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PORTABLE ELECTRIC TESTING APPARATUS.

By C. J. H. WOODBURY, OF BOSTON, MASS.

[Read before the Franklin Institute, April 18, 1883.]

The use of electricity for lighting purposes has introduced a new element in the matter of testing such systems. Hitherto the sole object in testing telephone, telegraph and other signal lines was confined to purposes connected with the operation or repair of the apparatus.

Electric faults in the telegraph never injured person or property. Contact with telephone lines never robbed a fire department of its right arm by destroying the fire alarm boxes. There is no instance of these weak currents ever setting fires or causing severe personal injuries like those which have been traced to electric lighting currents.

The difficulties connected with the introduction of the electric light have been inseparable with the use of a new form of energy, for the currents have been so much greater than those hitherto used that their application was virtually a new science. Twenty years after illuminating gas was known, the architect of the House of Commons specified that no woodwork should approach within six inches of a gas pipe.

Whenever an electric lighting current has been diverted from the system, it has generally given unwelcome evidence of its energy. Such occurrences, considered as an accidental loss of energy, are comparable

to the bursting of a boiler or the yielding of a dam; but there is no chance of such extensive injuries to life and property from any mishaps resulting from the use of electric-lighting apparatus.

Wherever the use of a large amount of power is involved, the safety is dependent upon the facility with which the whole is held under control, whether it be the head of water against the water-wheel, the steam in the boiler, or the electricity in the circuit. The experience with the electric light is showing that these currents are more easily controlled than other forms of energy, as far as any elements of danger are concerned.

It is not necessary at this time to recount any of the fires caused by electric lighting, but I am not aware of a single fire of this nature which, in the light of present knowledge upon the subject, is not to be considered as a preventable fire. With proper and *continual* attention to insulation, construction of lamps and of switches, and in the incandescent system also the proper size of conducting wires and *closed* safety catches, there can be so little opportunity for fire from electric lights that, under these conditions, it forms the safest method of illumination.

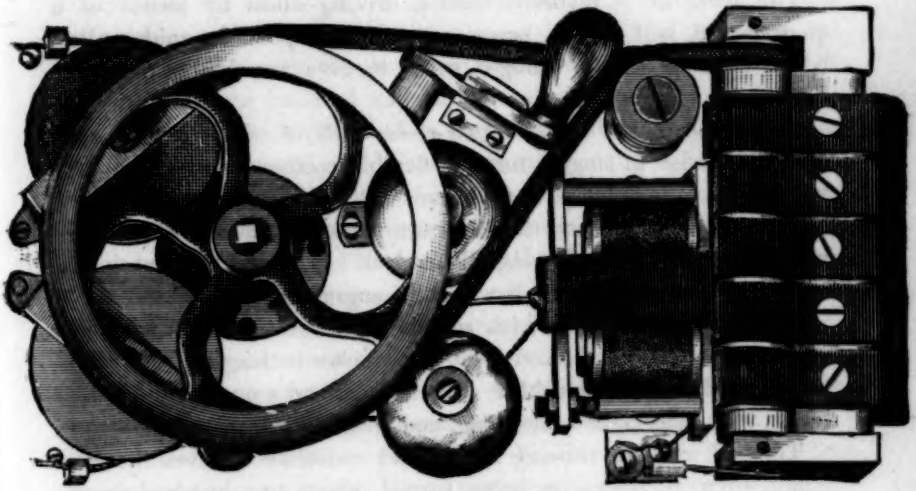
Most of the fires and other difficulties with electric lighting apparatus have been caused by the diversion of the current from the system at distant points, each leading to the earth, and very few accidents due to a conductor making a cross between two adjacent wires. Two contacts are required in order to form the complete circuit necessary to establish an electric current. If a single conductor leads to the earth, only a second one is necessary to divert a portion of the current from the system to the earth, the relative quantities of the current seeking the two paths being inversely proportional to their electrical resistances of the conductors.

Such a diversion of the electricity causes first the commercial loss of electricity. If the contacts are of a nature to diminish the resistance of the circuit, then there is great liability of injury to the armature or commutator in most dynamo machines. The fires have been produced where the electricity met with a conductor of sufficiently high resistance to convert the electricity into heat whose temperature is high enough to burn any combustible substance.

The instances usually occurred on a circuit where one ground connection already existed, and a stream of water leaking during storms, or from washing floors, running over the wires and to the earth formed a

good conductor, which was soon removed, as the electricity dissociated the water, and then an arc was formed as the current strove to maintain itself. Pure rain water is a very poor conductor of electricity, but, in trickling over plaster or whitewash, it takes enough lime or salt into solution to increase its conductivity many times. In some instances, the water connected two wires of diffenent potential. We see the same action when the current is let on an arc-lighting system. When the carbons touch, there is little resistance, and would be no light if the feeding apparatus was not arranged so as to draw the carbons apart and thus present the resistance of the space of the distance between the two carbons.

In the early application of electric-lighting apparatus, ground return



circuits were used as in other electrical circuits, but there were so many difficulties that it was abandoned and metallic circuits are now universally used. I believe Professor Edwin J. Houston, of Philadelphia, was the first one to indicate the dangers of using electric-lighting circuits with ground returns.

If an electric-lighting plant is well constructed and installed in a proper manner, there is no certainty that it will remain in a satisfactory condition on account of the numerous changes, blunders, and accidents to which it is subjected. It is important that each circuit should be provided with some apparatus for the purpose of making frequent tests of the insulation of the whole system. The most precise method

is to use a galvanometer, with a rheostat and battery, but this involves delicate and expensive apparatus, which cannot be used by any one except an electrician; while the weight and bulk of galvanometer, rheostat and ten cells of battery renders it impracticable for portable use.

The above engraving shows a portable instrument for the purpose of electric testing, made from my designs by Charles Williams, Jr., of Boston.

It consists of a Siemens' armature in the field of a battery of five permanent magnets. There is no commutator and the alternating current passes through the coils of a polarized electro magnet which vibrates a striker between two gong bells whenever the circuit is electrically complete.

The armature is revolved from a driving-wheel by means of a quarter-turn belt which passes around an adjustable guide-pulley, whose position can be changed so as to give any desired tension to the belt.

At the end of the case are two reels, each of which contain steel tapes thirty feet in length, forming flexible conductors which are provided with spring clamps at their ends.

The driving-wheel and the reels are turned by means of a crank which fits with square dowels, like a clock key, and when not in use is held by a spring clip as shown in the engraving.

The armature is wound with six thousand feet of No. 40 wire, and measures one inch in diameter, by three inches in length. The whole is contained in a hard rubber case, an inch and a quarter thick, four inches wide, and eight inches long, and weighs three pounds.

The bell will ring through an external resistance of seven thousand ohms, when the crank is being turned, about two hundred times a minute. When the crank is turned more rapidly, the bells can be made to ring through a greater resistance; the limit being about ten thousand ohms, when the crank is revolved as rapidly as one is able to turn.

As a basis of comparison between the limits of this instrument and other methods commonly used in testing, I made some experiments with a vibrating bell (called a jingler) and a compass galvanometer of low resistance.

The resistance of the coils on the electro-magnet of the vibrating bell was two ohms; and with one cell of Leclanché battery, the bell

would ring through a resistance of ten ohms. With a cell of bichromate of potash battery, the bell would ring through a resistance of twenty ohms.

The compass galvanometer was one of those used for testing circuits, the resistance of the coils being eighteen-hundredths of an ohm. The diameter of the graduated circle around the needle was one and a quarter inches, and ten degrees was about the smallest deflection which could be noted under ordinary circumstances. With one cell of Leclanché battery, the needle of the galvanometer would deflect ten degrees through a resistance of seventy ohms. With a cell of bichromate of potash battery, it would make a similar deflection through a resistance of one hundred ohms. More delicate results could have been obtained with galvanometers of higher resistance, but care was taken to use the exact kind of galvanometer made and sold for such purposes.

In comparison with this, my testing magneto will operate through a resistance three hundred and fifty times as great as the vibrating bell with bichromate of potash battery, and seventy times that of the compass galvanometer with the same battery; when a Leclanché cell is used, the ratio is doubled.

These quantities represent the relative delicacy of operation between the vibrating bell and the portable galvanometer with battery as described, and my testing magneto, which requires neither battery nor coils of conducting wires, being complete within itself.

One of the armatures was provided with a commutator, and the following measurements taken with the resistance of the armature amounting to four hundred ohms as the only resistance in the circuit:

Revolutions of crank per minute.	Electro motive force in volts.	Current in amperes.
60	2·00	·0050
120	3·96	·0099
180	6·04	·0151
240	7·96	·0199

The whole efficiency of the testing apparatus depends upon its ability to detect any ground which could, under any circumstances, become an element of danger. The resistance of the

arc-lighting circuits (cold) is very variable, owing to the irregular resistance between the tips of the carbons.

A number of measurements of long arc-lighting circuits show that one and a half ohms to a lamp is a fair estimate for the external circuit, as the connections are usually made. This, on a forty light Brush circuit, would be sixty ohms, and when the bell of the testing magneto can ring through a resistance of seven thousand ohms, it is able to indicate a possible escape of six-sevenths of one per cent. of the current, which, in the Brush system, amounts to nine-hundredths of an ampere or about four and half times the quantity generated by the testing magneto, an amount of energy to small to cause any damage whatsoever.

The same method applied to other circuits show still smaller results, as the resistance of a Brush forty-light circuit is greater than that of the circuit from any other dynamo.

With the low resistances used in incandescent lighting systems, the limit of measurement is still greater. In a one hundred light Edison incandescent plant, this tester would detect a leakage of less than one twenty-fifth of one per cent. of the current used in the whole circuit, or, in this instance, it would show a leakage of one twenty-fifth of the current required for a single sixteen candle-power Edison lamp, which would amount to twice the amount of current generated by the testing magneto.

The method of using the instrument to test for ground connections is to fasten one of the spring clamps to a conductor leading to the earth, such as the stop-cock to a gas pipe, or preferably to a water pipe, and the other spring clamp to the lighting system. When resistance of the insulation between the system and the earth is less than seven thousand ohms, the bells will ring.

If the crank is turned slowly, the bells will ring only through less resistances, and by standardizing these testing magnetos by measuring the limits at various speeds by means of a rheostat, they can be used to approximately measure resistances by counting the speed of the crank necessary to ring the bells.

For testing the insulation of arc lamps, if one clamp is attached to one of the binding posts of the lamp, and the other clamp placed in contact with the various parts of the frame while the armature is revolving, the ringing of the bells will indicate imperfect insulation.

Whenever it is desired to test incandescent systems for crosses, this

apparatus can be used for the purpose by disconnecting one of the main conductors from the dynamo and turning every lamp switch on the circuit; if the lamp sockets are not provided with independent switches, then such lamps must be removed. Care must be taken that the resistance box does not close the circuit. Then attach one of the spring clamps of the testing magneto to each main conductor, and a ring will detect the presence of a cross conductor. By switching off the various branches and testing in sections, any fault can be located to that single branch, and the safety boxes furnish a means for further divisions of the circuit.

This apparatus requires no electrical skill for its use, is not affected by time or temperature, and can be used in any position. They have stood the test of over a year's constant use, without accident or deterioration of any nature.

NOTE RELATING TO A PECULIARITY DISTINGUISHING ANNEALED FROM UNANNEALED IRON.*

By Prof. R. H. Thurston.

The writer has had occasion, recently, to study the effect of prolonged stress upon the various materials in common use in the arts, and, among others, upon the finer qualities of iron. The well-known experiment of Vicat, made half a century ago, had never, so far as the writer was aware, been repeated. The extreme importance of the results obtained by him had, apparently, not been realized by either physicists or engineers, and it seemed advisable that the experiment be repeated, and should the results obtained by Vicat be again reached, that the attention of both scientific and practical men should be again called to the subject. The repetition of Vicat's experiment has not only confirmed his conclusion, but has led to the discovery of a new and important, as well as peculiarly interesting, difference in the effect of prolonged stress upon annealed and unannealed iron.

In the autumn of the year 1881, the writer procured two lots of the best Swedish iron wire from Mr. Wm. Hewitt, Vice President of the Trenton Iron and Steel Works, who very kindly had the wire drawn for the purpose. This wire was divided into two parts, one being

* From advance sheets of *Science*.

carefully annealed, the other being left hard-drawn as it came from the blocks. These were tested in the usual way and it was found that the hard wire had about double the strength of the soft. Nine pieces were taken from each reel for test under prolonged static stress and were suspended from hooks, in the study of the writer, attached to springs in order that the effect of jar should not enter into the experiment.

They were then loaded with respectively, in each set, 95, 90, 85, 80, 75, 70, 65, 60, 55 per cent. of the average ultimate strength, as already determined. This was done in November, 1881. Since that date, a number have broken, as follows:

Effect of Prolonged Stress.—Swedish Iron Wire.

Per cent. max. static load.	Time under stress.	
	Hard wire (unannealed).	Soft (annealed).
95	80 days	8 minutes.
90	35 "	5 minutes.
85	17 months, unbroken	1 day.
80	91 days	206 days.
75	Unbroken	17 days.
70	"	455 days.
65	"	455 days.
60	"	Unbroken.
55	"	"

Thus, wire loaded with but 60 per cent. of the breaking load, as usually determined, broke after being subjected to stress for a period of fifteen months when annealed; while hard wire carrying 85 per cent. of the maximum temporary load remains unbroken after seventeen months. It is seen that these results are the same in kind as those obtained by Vicat, and confirm the conclusion that heavily loaded iron, as well as other metals and the woods, are likely to yield ultimately under loads that are sustained for short periods of time without apparent injury. This fact has been amply proven by earlier investigators, as well as by the writer; but the difference, above

observed, between hard and soft iron has, so far as the writer has been able to learn, never, until now, been discovered.

Although the experiments, of which this is the first, are not yet concluded, this discovery, if such it prove, has seemed to be of sufficient importance to justify this note.

AN EXTENSION OF THE THEOREM OF THE VIRIAL AND ITS APPLICATION TO THE KINETIC THEORY OF GASES.

By H. T. Eddy, C. E., Ph. D., University of Cincinnati.

(Concluded from page 348.)

4. Relation of the Molecular Forces to Temperature, Volume and Pressure. Expression for Work done, and the Second Law of Thermo-Dynamics.

The first member of (13) is the mean energy of the progressive molecular motion of a unit of gas; and since heat is known to be energy, this energy is assumed to be part of the sensible heat existing in the gas—the total sensible heat being the total kinetic energy, progressive and rotary and vibratory, existing in the gas.

Let k be the specific heat of the gas at constant volume measured in mechanical units, and let τ be the absolute temperature; *i. e.*, the zero of temperature is a state devoid of kinetic energy; then the statement just made is expressed by the equation

$$\tfrac{1}{2}\,\Sigma_1^n m\,(x'^2 + y'^2 + z'^2) = a\,k\,\tau, \qquad (26)$$

in which a denotes what fraction of the total heat-energy, $k\tau$, contained in the gas, exists in it in the form of progressive molecular motion. It seems to be pretty well established by experiment that a is very nearly, if not quite, constant for permanent gases; and by permanent gases is meant any gas or vapor above the critical temperature above which it is uncondensable by pressure alone. This definition of permanent gases includes of course imperfect gases having intermolecular attractions of sensible magnitude.

From (26) and (13)

$$a\,k\,\tau = \tfrac{2}{3}\,p\,v + \tfrac{1}{2}\,\Sigma\,r\,R \qquad (27)$$

When the last term of (27), which is dependent upon the intermolecular attractions, is so small that it can be neglected, this equation

expresses the empirical law of Gay Lussac for the so-called perfect gases, and it also includes Boyle's law.

But, in order to treat permanent gases, these attractions must not be disregarded. Retaining, then, all the terms, let a variation of state of the gas occur, the relation between the variations in any change of state of the gas will be expressed by the equation

$$a\,k\,d\,\tau = \tfrac{2}{3}\,(p\,d\,v + v\,d\,p) + \tfrac{1}{2}\,\Sigma\,(R\,d\,r + r\,d\,R), \qquad (28)$$

which admits of several comparisons with experimental results, which are of considerable importance in enabling us to correctly estimate the effect of the intermolecular attractions. These comparisons will be made later in the paper.

While speaking of their attractions, it should be remarked that were it possible to actually remove all attractions between molecules which themselves occupy an appreciable fraction of the total space in which they move, the effect of their mutual encounters could be considered to be that of a feeble repulsion, for their centres cannot approach within a certain small distance of each other without experiencing an insuperable repulsion; but this effect is better taken into account by regarding the volume v not as that of the total space occupied by the gas, but as the free space remaining after deducting that actually occupied by the molecules themselves. The space so occupied may be taken to be approximately that of the gas when condensed to the liquid state. Our formulæ may then be all rendered more exact by defining v to be this free space.

To obtain the work done during the expansion of a gas, divide (27) by $\frac{2}{3}v$ and multiply by dv.

$$\therefore p\,d\,v + \tfrac{1}{3}\,\Sigma\,r\,R\,\frac{d\,v}{v} = \tfrac{2}{3}\,a\,k\,\tau\,\frac{d\,v}{v}. \qquad (29)$$

But v varies as r^3,

$$\therefore v = c'\,r^3, \quad \therefore \frac{d\,v}{v} = \frac{3\,d\,r}{r}. \qquad (30)$$

Substitute in the second term of (29)

$$\therefore p\,d\,v + \Sigma\,R\,d\,r = \tfrac{2}{3}\,a\,k\,\tau\,\frac{d\,v}{v}. \qquad (31)$$

The first member of this important equation, which is due to Clausius,* expresses work done, the first term being that done against

* *Phil. Mag.*, S. 4, vol. 50, p. 195, 1875.

external forces, and the second term that done against the intermolecular attractions.

If the increment of the total work done be denoted by dw, and if, for compactness, we put $dv \div v = d \log. v$, (29) becomes

$$dw = \tfrac{2}{3} a k \tau d \log. v. \tag{32}$$

If the increment of the total energy in all forms supplied to change the volume and temperature of the gas be dh, then

$$dh = k d\tau + dw \tag{33}$$

Now substitute the value of dw from (32)

$$\therefore dh = k d\tau + \tfrac{2}{3} a k \tau d \log. v \tag{34}$$

Divide (34) by τ, etc.

$$\therefore \frac{dh}{\tau} = k d [\log. \tau + \tfrac{2}{3} a \log. v], \tag{35}$$

from which it appears that the first member of (35) is a perfect differential; hence the second member is. But this is, as is well known, the fundamental equation of the second law of thermo-dynamics. It is to be remarked that it has been here assumed that a and k are constants, which they undoubtedly are very nearly, if not exactly, as will be shown later.

5. Experimental Verifications and Comparisons.

The equations (28), (31), etc., respecting the variations of temperature, volume and pressure of a permanent gas, are general, and, as a particular case, we shall first consider the experiments of Thompson and Joule* in causing air and other gases to expand freely in passing through a porous plug. In these experiments the variation of temperature is very slight, and the gases obey so nearly the law of Boyle, that we are at liberty to assume in (28), $d(pv) = p dv + v dp = 0$.

Hence (28) becomes

$$a k d\tau = \tfrac{1}{2} \Sigma (R dr + r dR) \tag{36}$$

In some of these experiments the gas, in passing the plug, expanded to more than four times its initial volume, so dr, the increment of the mean distance r of the molecules, must have been a considerable fraction of r. The terms in $R dr$ must be positive if the forces are attrac-

* *Phil. Trans. Lond. R. Soc.*, 1853, 1854, 1862; or *Wüllner's Experimentalphysik*, 3te Aufl. Bd. 3, S. 463.

tive, and express the work performed in moving the molecules through the distance dr from each other against the attraction R. According to (36), if these were the only terms in the last member, or the larger ones, the temperature, *i. e.*, the kinetic energy, would be increased by passing through the plug, a result which would be in palpable contradiction to the principle of the conservation of energy; for $R\,dr$, the work done, must have been extracted from the internal energy of the gas, which would cause a decrease rather than an increase of temperature. The experiments gave a slight decrease of temperature, which shows that the terms in $r\,dR$ are, in this case, negative, and numerically larger than those in $R\,dr$.

Let us examine this point more at length. Since there was almost no variation of temperatue, R may, in this case, be taken to be a function of r expressed by the equation $R = fr^{-i}$, in which f is a numerical coefficient and i is a number for which various values (all greater than unity) have been proposed by different physicists in order to represent the actual attraction, more or less approximately, by the proposed equation.

$$\left.\begin{array}{ll} \text{If} & R = fr^{-i}, \\ \text{then} & R\,dr = fr^{-i}\,dr, \\ \text{and} & r\,dR = -\,ifr^{-i}\,dr, \\ \therefore & r\,dR = -\,iR\,dr, \end{array}\right\} \qquad (37)$$

from which it appears that the terms in $r\,dR$ are, on this supposition, of opposite sign from those in $R\,dr$ and i times as large; and (36) becomes

$$ak\,d\tau = \tfrac{1}{2}f(1-i)\,\Sigma\, r^{-i}\,dr, \qquad (38)$$

in which the second member is negative if $(1-i)$ is so, a result which is, as already stated, in agreement with experiment.

Far more decisive are the experiments of Andrews* upon the behavior of carbonic acid gas above the critical temperature. In these experiments the pressures were carried to more than 100 atmospheres, at different constant temperatures, in which case (28) becomes

$$-\,d(pv) = \tfrac{1}{3}\,\Sigma\,(R\,dr + r\,dR). \qquad (39)$$

By (37) this may be written

$$-d(pv) = \tfrac{1}{3}f(1-i)\,\Sigma\, r^{-i}\,dr. \qquad (40)$$

* *Phil. Trans. Lond. R. Soc.*, 1869, p. 575; or *Wüllner's Experimentalphysik*, Bd. 3, S. 680.

The following are the numerical results obtained at the temperature of 48·1°C., in which p is given in atmospheres, and the volume, v, of the gas, at one atmosphere, is taken as 1000:

p	v	pv
62·60	11·57	724·28
68·46	10·06	688·70
75·58	8·49	641·67
84·35	6·81	564·42
95·19	5·04	479·55
109·40	3·35	366·40

In treating this experiment as a compression, dr is negative, and both members of (39) are then positive, while $r\,dR$ is shown by the numerical results to be much larger than $R\,dr$, and of opposite sign. Other results at temperatures nearer the critical temperature of 31°C. are perhaps more striking than that just quoted.

The experiments of Andrews, as well as those of Regnault and other physicists, have shown conclusively that, according as the temperature of an imperfect gas is augmented, it becomes more and more nearly perfect; *i. e.*, it approaches more nearly to the state in which there are no intermolecular forces. Hence, R is also a function of τ, and such an one that dR is negative when $d\tau$ is positive; from which it appears that in (28) the terms in $r\,dR$ are in all cases of different sign from those in $R\,dr$. In fact, if the volume remains constant, the terms in $R\,dr$ vanish, because $dr = 0$ by (30).

Hence, combining this result with that previously arrived at, we see, if temperature and pressure be taken as the independent variables, that since $\Sigma\, d(rR)$ is negative for increments of each of these variables separately, it is so for both together, and hence is so always.

As another interesting example of the comparison of (28) with experimental results, let us consider Berthelot's* principle of the maximum work (*i. e.*, maximum heat) of chemical decomposition, which states that every chemical change accomplished without the intervention of energy from without, tends to the production of the body, or system of bodies, which sets free the most heat.

This is announced as a law of nature, the proof of which is to be found in a vast array of experimental evidence. It is evidently a law of fundamental importance to the theory of chemistry; and it seems

* *Essai de Mechanique Chimique*, 1879, t. 2, p. 421.

to depend theoretically upon the mechanical principles involved in (28), for at the instant of chemical decomposition the atoms must be regarded as separate bodies obeying the laws of stationary motion.

In order to introduce the condition of no exchange of energy with external bodies,

Let $$d v = 0, \ \therefore p\, d v = 0;$$

i. e., there is no work done against external pressure, and if $v\, d p$ be small enough to be neglected, then (36) may be applied to this case. It appears, however, that the ordinary conditions of experiment from which the law was deduced would be better represented by supposing the pressure constant;

$$i.\ e., d p = 0, \ \therefore v\, d p = 0,$$

in which case $p\, d v$, the external work, is, as appears from experimental evidence, in general so inconsiderable as not to affect the correctness of the result, so that (36) may be considered, in this case also, to express approximately the mechanical relations involved. Considering now the case of $d v = 0$, the terms in (36) in $R\, d r$ are inconsiderable, since the mean distance cannot be greatly changed while the total volume remains constant. But the terms in $r\, d R$ depend principally upon the increase dR; *i. e.*, of the attraction between the atoms in the final chemical combination over that in the initial. If the atoms in the final arrangement obey the greater attractions, then $r\, d R$ is positive. But $r\, d R$ is numerically greater than $R\, d r$; hence by (36) heat is liberated, and the temperature is augmented. Hence, Berthelot's principle—that of several possible chemical decompositions in an isolated body, that one will occur which sets free the largest quantity of heat—follows as a direct consequence of the axiomatic truth, that the atoms will obey the more powerful attractions, which will necessarily determine the rearrangement of the atoms into molecules.

As further examples of the application of our formulæ, it may be noticed that (38) can be employed to discuss the stationary motion of other systems besides that of the molecules of a gas, such as orbital and central motions, in which we have $p = 0, \ \therefore d (p v) = 0$.

Let e be the mean progressive energy of the system, then (38) becomes

$$d e = \tfrac{1}{2} f (1 - i) \Sigma r^{-1} d r. \qquad (41)$$

The only work done in changing the mean distances is

$$d w = \Sigma R\, d r = f \Sigma r^{-1} d r. \qquad (42)$$

And the total energy supplied to the system is

$$d\,h = d\,e + d\,w = \tfrac{1}{2} f\,(3 - i)\,\Sigma\, r^{-1}\,d\,r, \qquad (43)$$

from which it is seen that

$$d\,e = \tfrac{1}{2}\,(1 - i)\,d\,w, \qquad d\,h = \tfrac{1}{2}\,(3 - i)\,d\,w. \qquad (44)$$

Take the case of the solar system in which $i = 2$, then by (44)

$$d\,e = -\tfrac{1}{2}\,d\,w, \qquad d\,h = \tfrac{1}{2}\,d\,w.$$

The first of these equations states that if the mean distances of the bodies of the system are slightly augmented, then the mean kinetic energy of the system in this new state of stable motion is less than it was before by one-half of the work expended in moving the bodies to their new positions against their mutual attractions. The second equation states that the total energy which must be supplied is only half the work expended, the other half being derived from the decrement of the kinetic energy just mentioned.

Next take the case of an elastic system in vibration, in which $i = -1$, then by (44)

$$d\,e = d\,w, \qquad d\,h = 2\,d\,w.$$

These equations state the well-known fact that in this case the kinetic and potential energies are equally increased.

It is to be noticed that when $i = 3$ no energy need be supplied to the system to augment the mean distances, and when i is greater than 3 energy must be supplied to decrease the mean distances,—a remarkable fact to be considered in connection with the value $i = 5$, which was proposed by Maxwell.*

6. Ratio of the Specific Heats of Permanent Gases.

Let $\varkappa\, k$ be the specific heat at constant pressure, and k that at constant volume expressed in mechanical units; then their ratio $\varkappa$ is the quantity in question, which has been determined experimentally for a number of gases with considerable accuracy. Its approximate theoretical value can be found as follows:

If (33) and (28) be applied to this special case, in which $d\,p = 0$, we have, by definition of $\varkappa\, k$, $d\,h = \varkappa\, k\, d\,\tau$.

Also,

$$d\,w = p\,d\,v + \Sigma\, R\,d\,r, \qquad (45)$$

in which $p\,d\,v$ is the external work done, and the last term is the

* *Phil. Mag.*, S. 4, vol. 35, p. 133, 1868.

work done against intermolecular attractions. It will be noticed that there is no term in $d\,w$, as given, representing the work expended against interatomic forces. Were such a term needed, it would be also of the form $\Sigma\, R\, d\, r$, but its value is zero; for, suppose a molecule to consist of atoms held by elastic forces at certain mean distances, then these mean distances are not essentially changed by atomic vibration which alternately increase and decrease those distances, *i. e.*, $d\, r = o$ for each molecule. The periodicity of the lines in gaseous spectra observed by Stoney and Reynolds* shows pretty conclusively that the interatomic forces are of this character.

Hence, by (28),

$$d\, w = \tfrac{2}{3}\, a\, k\, d\, \tau + \tfrac{1}{3}\, \Sigma\, (2\, R\, d\, r - r\, d\, R). \tag{46}$$

Now let

$$\Sigma\, R\, d\, r = \beta\, k\, d\, \tau, \tag{47}$$

in which β is an extremely small positive numerical coefficient (which is zero for perfect gases), expressing what fraction the work performed against the intermolecular attractions is of the total increment of the kinetic energy. Then, by (37) we have the following approximate value of the last term of (46),

$$\tfrac{1}{3}\, \Sigma\, (2\, R\, d\, r - r\, d\, R) = \tfrac{1}{3}\, (2 + i)\, \beta\, k\, d\, \tau. \tag{48}$$

Substitute the values just given for the various terms of (33), and divide by $k\, d\, \tau$, and we obtain

$$\varkappa = 1 + \tfrac{2}{3}\, a + \tfrac{1}{3}\, (2 + i)\, \beta, \tag{49}$$

in which the value of a requires more extended consideration. Let b denote what fraction the increment of the mean rotary energy is of total increment $k\, d\, \tau$ of the kinetic energy, and let γ denote what fraction the vibratory energy, kinetic and potential, of the atoms within the molecule is of the same quantity.

Since these together constitute the total increment of the kinetic energy, we have

$$a + b + \gamma = 1. \tag{50}$$

But, in the general case, in which the molecules consist of more than two atoms, we have, by (13) and (23),

$$a\, k\, d\, \tau = b\, k\, d\, \tau + \tfrac{1}{2}\, \Sigma\, d\, (r\, R), \tag{51}$$

but by (37) and (47) this becomes (after dividing by $kd\tau$),

$$a = b + \tfrac{1}{2}\, (1 - i)\, \beta. \tag{52}$$

* *Philos. Mag.*, S. 4, vol. 42, p. 41, 1871.

Add (50) and (52)

$$\therefore \quad 2a = 1 - \gamma + \tfrac{1}{2}(1 - i)\beta. \tag{53}$$

Substitute this value of a in (49)

$$\therefore \quad \varkappa = \tfrac{4}{3} - \tfrac{1}{3}\gamma + \tfrac{1}{6}(5 + i)\beta, \tag{54}$$

from which it appears, that when the vibratory energy is considerable, it will have an important influence in diminishing $\varkappa$, while the intermolecular attractions may exert some slight influence to increase $\varkappa$.

The experimental values of $\varkappa$, as given by Meyer,* lie between 1·33 and 1·25. If we disregard the terms in β, the corresponding values of γ are 0 and $\frac{1}{4}$. The larger values of γ belong, in general, to the more complex molecules, and we seem here to have an experimental measure of the amount of the mean vibratory energy, kinetic and potential. If β is large in these gases, then γ is thereby increased.

In the case, however, in which the molecules consist of but two atoms each, we have by (25) the following equation instead of (52):

$$\tfrac{3}{5}a = b + \tfrac{1}{5}(1 - i)\beta, \tag{55}$$

which combined with (50) and (49) gives

$$\varkappa = \tfrac{7}{5} - \tfrac{2}{5}\gamma + \tfrac{1}{5}(4 + i)\beta. \tag{56}$$

In this equation it is seen that β has a somewhat greater influence than it had in (54), while γ has probably a much less influence; there being but one pair of atoms to vibrate instead of three or more pairs, as in the previous case, the value of γ itself would, in general, be much smaller than before.

The most probable experimental values of $\varkappa$ for H_2, O_2, N_2, CO, NO, HCl, and air all lie between 1·41 and 1·39, that for air having been many times determined by the ablest experimental physicists. The mean value of $\varkappa$ for air, from many accordant determinations, is 1·405, while the value derived from Regnault's most accurate measurement of the velocity of sound is 1·3945, which numbers are taken from Wüllner,† who gives an extended account and comparison of these determinations.

In the case in which the molecules consist of a single atom each, we have

$$b = 0, \therefore a = 1 - \gamma \tag{57}$$

* Kinetische Theorie der Gase, 1876, S. 91.

† Experimentalphysik, 1875, Bd. 3, S. 461.

in which case (49) becomes

$$\varkappa = \tfrac{5}{3} - \tfrac{2}{3}\gamma + \tfrac{1}{3}(2+i)\beta. \qquad (58)$$

The vapor of mercury is perhaps the only gas regarded by chemists as consisting of molecules of a single atom each, and for this gas, Kundt and Warburg* found $\varkappa = 1{\cdot}67$. The value of $\varkappa$ could also have been discussed by application of Clausius' equation (34) to the case of expansion at constant pressure, and results could thus have been obtained similar to those already found.

7. Concluding Remarks Concerning the Constitution of Gases.

The results which have been arrived at seem so to harmonize known facts respecting gases as to lend probability to the following statements:

(1.) Atoms have size and are smooth spheres—*i.e.*, are centres of force repulsive at very minute distances, and attractive at somewhat larger distances.

(2.) Molecules are systems of atoms held together by the atomic attractions and repulsions in which the mean distances of the atoms are not essentially changed by temperature or pressure, and probably not by liquefaction or solidification.

(3.) The mean rotary energy of the molecules is very nearly equal, in general, to their mean progressive energy; but is only two-thirds as much for diatomic molecules, and is zero for monatomic molecules.

(4.) The vibratory energy of the atoms within the molecules may be a considerable fraction (as much as one-fourth in the case of very complex molecules) of the total kinetic energy, and this vibratory energy should be regarded as wholly kinetic.

It has been thought improbable that the comparatively moderate progressive velocities of the molecules should originate the radiations of heat and light emitted by a gas, and hence that the atomic vibrations, which must be much more rapid, should be regarded as their mechanical cause. It has been then said that the energy of the vibratory motion set up within a molecule by an encounter must be rapidly expended in emitting radiations. Such, however, does not appear to be the fact, for in case radiations are caused by vibrations, then vibrations would apparently be caused as well by radiations from other bodies;

* Pogg. Ann., 1876, Bd., 157, S. 353.

so that a gas in equilibrium would thus receive the same amount of vibratory energy from without in the form of radiations as it loses. The vibration may, however, not be of uniform character during the interval between one molecular encounter and the next; it may take on a more regularly harmonic character as this interval elapses, and the energy of the irregular vibrations, or high harmonics, set up by the shock of the encounter may become transformed by the elastic forces into vibrations of less period, so that in a very rare gas, in which the encounters are comparatively infrequent, almost no vibrations, except those of an harmonic character, may be distinguishable.

At the same time, that part of the kinetic energy of the gas which is vibratory (the relative amount of which is evidently controlled by fortuitous molecular encounters) probably suffers no change by the frequency or lack of frequency of molecular encounters, in case any small amount of dissociation present may be disregarded. These considerations go to show that the fractions a, b and γ, which have been used, are of constant value, and that k must be so also.

Watson* in his treatise has investigated the ratio of the specific heats of a gas by the aid of generalized co-ordinates, expressing the number of degrees of freedom of the system of atoms in a molecule, and, though the investigation is one of great merit, it seems to me unsuited, in one particular, to the system treated; for it presupposes, as I understand it, rigid connections between the members of the system. Since an elastic connection is neither a degree of perfect freedom, nor of perfect constraint, but something intermediate, there is no integral number of degrees of freedom in the system. If molecules were rigid bodies, such systems would possess in general six degrees of freedom, and thus would have six generalized co-ordinates, which might be taken as three rectangular and three angular co-ordinates, such as have been employed in this paper. When, however, the molecules are smooth solids of revolution, the number of co-ordinates would be reduced to five, and, in case of smooth spheres, to three.

Now, if these are degrees of perfect freedom, it seems demonstrable that the kinetic energy which is distributed among them by fortuitous encounters would be equally shared by them—*i.e.*, the energy with respect to each co-ordinate would be of the same amount, a result which agrees with what has already been proved for perfect gases. But in case partial constraints, not amounting to the loss of entire

* Kinetic Theory of Gases, 1876, p. 38.

degrees of freedom, are introduced with respect to any of the co-ordinates, the energy will no longer be equally distributed among all the co-ordinates, but will be influenced by these constraints. This is what was found to take place in imperfect gases, where the intermolecular attractions affect the components of the progressive motion, but not the rotary components.

In many points the results arrived at in this paper are in substantial accordance with those found by Boltzmann* in his important papers upon this subject; but both he and Watson regard some of the experimental values of $\varkappa$, and in particular all values less than 1·33, to be in contradiction to theory. So far as is known to the author, the investigation which he has here given to the question explains for the first time this contradiction which Watson (p. 39) regards as "the great difficulty in the establishment of the kinetic theory of gases on the molecular hypothesis."

CINCINNATI, January 18, 1883.

ANTICYCLONIC STORMS.

By PLINY EARLE CHASE, LL.D.

The science of Meteorology may, for many good reasons, be regarded as a peculiarly American science. William Ferrel's discussion of the motion of fluids and solids relative to the earth's surface, which was first published in the summer of 1856, placed the laws of cyclonism and anticyclonism on a solid mathematical basis. He showed that, in the northern hemisphere, all moving bodies are constantly subjected, in consequence of the earth's rotation, to a deflection towards the right hand. Hence all atmospheric surface currents which are mainly governed by a downward pressure, tend to curve in the direction of the hands of a watch, or successively through north, east, south, west. All surface currents which are mainly governed by an upward pressure, tend to flow in an opposite direction, or through north, west, south, east.† The heavy winds are called anticyclonic; the light winds, cyclonic.

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* Sitzungsb. d. Wien. Akad., Bd. 63, 66, 74.

† This will be evident, if we imagine ourselves to be lying in the current and facing the direction towards which the pressure tends.

There can be no descending currents in one place without ascending currents in another; therefore, in every atmospheric disturbance, there must be simultaneous cyclonic and anticyclonic winds. Such disturbances originate either in an unusual cooling and condensation, or in an unusual heating and expansion of air. In the former case the inflow, in the upper regions of the atmosphere, will produce an increased pressure. In the latter, the outflow will produce a diminution of pressure. In the restoration of equilibrium, currents of warm air are often brought into contact with colder currents. If the currents are both saturated wtth moisture, or if they contain more vapor than can be retained under the temperature of the mixed currents, precipitation takes place, in the form of rain, hail, or snow This precipitation reduces the weight of the atmospheric column and the barometer falls. Accordingly, there is a constantly increasing tendency to cyclonism about storm centres, and there has been a very prevalent disposition to look upon all storms as of cyclonic origin.

A little reflection, however, will show that the initial mixture of currents may be due to either of the causes above mentioned; either to the flow of warmer air into a cold depression at the top of the atmosphere, or to a flow of cold air, at the earth's surface, towards a region of low barometric pressure. In the former case, the initial superficial currents are determined by a downward pressure and they are, therefore, anticyclonic; in the latter they are determined by an upward pressure and are cyclonic.

A careful study of the weather maps shows that the heaviest rains and snows occur in advance of the centres of low barometric pressure, or in the rear of the centres of high barometric pressure. If storms began in the cyclonic currents, the reverse should be true; the greatest effect following the low centre and preceding the high centre.

The frequent failures of forecasts, during the past winter, seem to have been mainly due to a misinterpretation or a misconception of these facts, to which the writer first called attention in 1871 (*Proc. Amer. Phil. Soc.* XII, 40). They were subsequently embodied in the "Suggestions" of the Signal Service Bureau, and the officers of the Bureau communicated to the public journals, some remarkable evidences of anticyclonism in storms of great magnitude.

Loomis's subsequent discussions of the Signal Service observations have furnished abundant additional evidence of a like character, and

have shown the great frequency of anticyclonism at the beginning, and during the continuance of showers and of storms of all kinds.

The limit between anticyclonic and cyclonic tendencies, may be approximately assumed to be midway between the centres of high and low barometric pressure. All cloudiness or precipitation between the limit and the high centre, represents anticyclonic influence; all between the limit and the low centre represents cyclonic influence. Local cyclonism sets in soon after precipitation begins, and the anticyclonic influence is thus partially hidden; but a critical examination of the weather maps will show that the prevailing currents of the region often continue to be anticyclonic until the rain or snow is nearly, or quite over. The evidences of storm breeding and stormy anticyclonism will be still more striking, if the changes of barometric pressure are studied in connection with the beginnings and subsequent growth of cirrus, cumulus, and nimbus clouds, as well as with the rainfall and the final breaking up of cloudiness.

There are good reasons for believing that such study, systematically and thoroughly continued under the direction, and with the facilities of the Signal Service Bureau, would raise the successful verifications of the Washington forecasts to an average of at least ninety-five per cent.

THE GEOLOGY OF PHILADELPHIA.

By Professor H. Carvill Lewis.

[A lecture delivered before the Franklin Institute, January 12, 1882.]

Some years ago, Dr. C. C. Abbott, of Trenton, announced his discovery in this gravel of stone implements of human workmanship, distinct in shape and characters from those of the modern Red Indian. They are larger and more rude than modern implements, being roughly chipped and never ground to an edge or polished. Unlike modern arrowheads and spearheads, which are generally made from quartz, flint or some hard sandstone, these are all made of gray argillite, a rock which is found in places farther up the river, and which is a Triassic shale altered and hardened by the heat from adjacent trap dykes.

They are essentially of *palæolithic* type, and have identical characters with the river drift implements found in the valleys of France, England, and other parts of Europe. Dr. Abbott states that the modern implements ("neoliths") are confined to the surface of the ground or a few inches below, but are never associated with the "palæoliths" lower down, which may occur at depths of ten feet or more below the surface. When found below the surface, these palæolithic implements always occur in the Trenton gravel, and never in the older gravels, and this fact alone offers strong evidence that they belong to and are of coeval deposition with that formation. In going over the ground in company with Dr. Abbott, it was interesting to find that it was only within the limits of the Trenton gravel, as previously traced out and mapped by the lecturer, that these implements had been found below the surface. Many competent archæologists sustain Dr. Abbott in believing that these rude implements are a constituent part of the gravel, and are neither natural forms nor intrusive objects.

All the evidence that has been gathered points to the conclusion that at the time of the Trenton gravel flood, man in a rude state lived upon the banks of the ancient Delaware. He may have been in the habit of spearing fish and seals with spears pointed by his rough stone implements, and these having been dropped into the flood may have sunk into the loose and shifting gravel. The climate was cold and the flooded river was filled with icebergs. A similar period in Europe has been called the *Reindeer Period*.

It is interesting to find, as pointed out by archæologists, that until lately the Esquimaux have used rude stone implements similar in appearance to those found in the Trenton and other river gravels, and it has been suggested that that race, now living in a climate and under conditions perhaps similar to those once existing on the Delaware, may have some kinship with the pre-Indian people of this river. It may be that an Esquimaux race, living here at the time of the flooded Delaware, were driven north by the coming of the Red Indians.

Whether or not these ancient people were the ancestors of our present Indians, it is of interest to find their great antiquity, as shown by the Trenton gravel. As already stated, that gravel was deposited at the close of the last glacial epoch. The conditions at that time have already been described, and in the last lecture an attempt was made to calculate the probable date of that period. A careful search among

the more recent gravels underlying Philadelphia, might throw more light upon this yet unsettled problem.*

Coming now to the second portion of our subject, being a description of the *rocks* in the vicinity of the city, time forbids more than a cursory examination.

THE PHILADELPHIA GNEISS.

The above described superficial formations rest upon an ancient metamorphic rock, composed of quartz, felspar, and mica, arranged in layers, and known as *gneiss*, and thus frequently in the same street cutting a section may be exposed of one of the most recent deposits lying directly upon one of the most ancient geological formations known. The age of the glacier is as nothing in comparison with that of the gneiss. The latter forms the old foundation stones of the continent, from which all the other rocks were afterwards formed. The flakes of mica in the sandstones of the coal strata and in the brownstone used for our houses, are derived from this ancient formation of gneiss, which has been the bed of many an ocean. Underlying all the other rocks of the globe, the *Archaean* rocks were made at the time when the lowest forms of life were introduced. Of the archaean rocks, the oldest are the *Laurentian*, to which the gneiss near Conshohocken probably belongs, and the newer are known as *Huronian*. To this division belongs the gneiss at Philadelphia, which is identical with the gneiss which forms the White Mountains of Vermont and the Rocky Mountains of Colorado. From the former locality it is sometimes called *Mont-Alban*. These ancient rocks are always greatly twisted and contorted, generally dipping at high angles to the horizon, as may be seen along the Schuylkill in the East Park.

As the earth contracted during its cooling from the molten state, its crust shrivelled and became wrinkled like the skin of a dried apple. The strata were tilted up to form mountain chains, which were afterwards ground down by long continued erosion. No life could exist until the earth had cooled down to 200° F. Some idea of the length of time before that stage is given in Helmholz's calculation, based upon the rate of cooling of lavas, that for the earth to cool from 2,000° to

*At the opening of the lecture, Mr. John Sartain brought for examination a supposed Indian implement found by him in gravel, 24 feet below the surface of the street, in an excavation below the cellar of No. 728 Sansom street, Philadelphia. This implement has since been described in full by Prof. Lewis, in the Proceedings of the Academy of Natural Sciences, Feb. 6, 1883.

200° F., would have required three hundred and fifty millions of years. Any life that may have existed in the Philadelphia gneiss has been obliterated by the heat, pressure, contortions, and consequent metamorphism to which it has been subjected. These same forces, however, have made our rocks so full of interesting minerals. Minerals and fossils, therefore, rarely occur together.*

The beds of serpentine which occur in the gneiss of the northern part of the city, are regarded as the result of the alteration of gneissic rocks by contact with magnesian waters.

THE PRIMAL SLATES AND POTSDAM SANDSTONE.

On top of the gneiss and at the base of that great group of fossiliferous rocks known as the Palaeozoic system, is a peculiar formation in the middle strata of which occur the oldest fossils yet found in the vicinity of Philadelphia. The lower part of the formation is the pale sandy slate which forms Edge Hill and Barren Hill, and the northern base of Chestnut Hill. The slates are closely folded and stand often almost perpendicular. At Edge Hill station on the N. P. R. R., the strata are broken and bent over by the action of gravity draging them down hill—this phenomenon being known as "creep." These slates (known as hydro-mica slates) are probably of the same age as the diamond bearing slates of Brazil and elsewhere.

A sandstone, which from its great development at Potsdam, N. Y., has been named from that place, overlies the slates and often contains long tubular fossils, known as *Scolithus linearis*, which appear to be the casts of worm-holes. As shown by the ripplemarks, this sandstone was formed at the edge of an ancient sea. Marine worms burrowed in the sea beach and the winds drifted the sands, which ages afterwards were hardened and tilted up to form the rocks at Willow Grove, and those along the north side of Chester valley.

On top of this fosiliferous sandstone is a series of soft, iron-bearing shales, often decomposed into variegated clays, carrying extensive beds of iron ore (limonite). Crossing the limestone valley, diagonally, in a series of anticlinal rolls, which rise through the overlying limestone, this formation supplies a large amount of iron ores to our blast furnaces.

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* The principal minerals in the Philadelphia gneiss were given, and the boundaries of the formation were shown upon a map. It was stated that no accurate geological map of this region had yet been constructed.

THE AURORAL LIMESTONE.

The bluish-white streaked marble which adorns the door steps and window sills of the greater part of our houses comes from the limestone valley which, on either side of the Schuylkill, lies immediately north of the city. Originally formed by the accumulation of minute organic remains under deep sea water, subsequent changes have obliterated all traces of animal life, the streaks of carbonaceous material and the occasional specks of graphite alone remaining as witnesses. These same changes have altered certain strata of the limestone to the crystalline state known as marble. The quarries at Marble Hall are well worthy of a visit. Farther inland, in places removed from the disturbing influences of the Philadelphia region, the same limestone is filled with fossil shells and corals. Professor Rogers called it the "Auroral" limestone because it was the dawning of the long geologic day of the succession of Palaeozoic life.

Like almost all limestones, the Auroral limestone always occurs in a valley. These valleys, such as that north of Chesthut Hill, are such from the fact that the limestone for countless ages has been constantly dissolved away by the power of rain-water, and the surface lowered by the breaking down of underground caverns. On the other hand, the Kittatinny mountain is a mountain, not because its rocks are more tilted up than other rocks, but simply because the hard sandstone which forms it has resisted these atmospheric and erosive agencies, while the country on either side of it has been lowered.

The *iron ore*, so common in the valley north of Chestnut Hill, most of which is in the form of *limonite*, has been derived by solution and subsequent segregation from the older underlying shales, some of it having been altered in place from these shales, some of it belonging to clays of tertiary age, and some of it having been drifted still more recently and made a surface deposit. The lecturer several years ago discovered *lignite*, or brown coal, at some localities in the vicinity of Marble Hall. It had the form of twigs and branches, and, associated with kaolin, potter's clay and iron ore, threw light upon the age of these deposits.

THE TRIASSIC SANDSTONE.

A succession of red sandstone and shales, which, from its threefold division in Germany has been called the Trias, and which belongs to Mezozoic time, being more recent than the coal measures and older than the New Jersey marl, forms in Pennsylvania a belt, the lower edge of which extends from Trenton to Norristown and Valley Forge,

whence it traverses Berks, Lancaster, York and Adams counties, entering Maryland south of Gettysburg. The strata all dip at a low angle northwestward, and appear to have been deposited in a shallow estuary or inland sea which once occupied this region. As shown by the composition of its pebbles, this Triassic sea washed the shores of the Philadelphia mountains.

This was the age of reptiles. Labyrinthodonts waded in the mud-flats and left their tracks preserved to this day. Some of them walked altogether on their hind legs like a kangaroo, looking probably like a long-legged frog covered with scales, with teeth several inches long, and tall enough sometimes to look over a twelve-foot wall. Other creatures, called Dinosaurs, were like four-legged birds, the hind feet being bird-like. One of these, which had teeth like a crocodile, lived at Phœnixville, where its bones have been found. The footprints of these creatures, the mud cracks and ripple marks and rain prints, the cycads and tree ferns, and the occasional seaweeds, all tell the story of this formation and give fresh interest to that part of it which, under the name of "brownstone," is used for the fronts of our Walnut street houses.

As the Triassic age drew to a close, there was an outburst of volcanic action. Streams of molten lava issued from the earth to form the trap dykes which are crossed by the Reading Railroad at Conshohocken, by the North Pennsylvania Railroad near Quakertown, and by the Pennsylvania Railroad twenty miles before reaching Harrisburg.

The sketch here given of the geology of Philadelphia is but a fragment of what may be learned at our very doors. The gneiss of which our cellars are built takes us back in thought to that remote time when the earth had just cooled sufficiently to permit the introduction of the lowest forms of life; the marble of our door-steps tells of an ocean inhabited by no fishes, which washed land upon which grew no trees; our brownstone fronts recall an age of strange reptiles and uncouth birds, when seaweeds grew on the hills back of Norristown, and when earthquakes cleft open the earth; the bricks of our walls teach us of an epoch when the city was under water, the Schuylkill joined the Delaware at the Falls, and icebergs floated down from the great glacier farther north; and the cobble-stones, finally, mutely speak of that age of cold, preceding our own, when the glaciers melted and retreated, and when, on the banks of the flooded Delaware primeval MAN first appeared.

REPORT OF THE SPECIAL COMMITTEE OF THE FRANKLIN INSTITUTE ON THE PREVENTION OF FIRES IN THEATRES.

[Presented and accepted at the stated meeting of the Institute held Wednesday, April 18, 1883.]

HALL OF THE INSTITUTE, April 18th, 1883.

The majority of the "Committee on Prevention of Fires in Theatres" makes the following report:

Theatres for two hundred years have not materially changed in form or arrangement, yet they have enormously increased in size.

The building materials employed for the stage have, however, remained the same (except that in many cases the joists of the stage floor are I beams of iron); they are at present, as they formerly were, filled with masses of wood-work, boards, laths, canvas, gauze, etc., piled up as if it was the sole purpose of the builders to crowd together as many inflammable substances as possible.

The only important changes in theatres have been, first, the introduction of gas lighting; and second, appliances for heating, both of which have tended to greatly increase the hazard.

Without going into any detailed statistics, your committee shall give a few tables, compiled from the records of Foelsch and Hexamer, which are particularly instructive and interesting. For example, of 616 theatre fires there have occurred:

In London	35
In Paris	29
In New York	27
In San Francisco	21
In Philadelphia	17
In Boston	11
In Cincinnati	9
In New Orleans	8
In Baltimore	6

It is an alarming fact that the number of theatre fires is continually increasing. Sixty-nine occurred between 1851 and 1860, ninety-nine occurred between 1861 and 1870, 181 occurred between 1871 and 1880.

During the last decade we have had theatre fires as follows:

1871	20
1872	13
1873	15
1874	15
1875	14
1876	19
1877	17
1878	20
1879	25
1880	23
1881	28
Total	209

Average, 19.

Nineteen theatres have therefore on the average been destroyed during the last eleven years.

In a recent compilation your committee found that in 1882 twenty-three theatres were destroyed by fire.

Out of a great number of theatres, of which the age had been carefully ascertained, it is found that five out of two hundred and fifty-two theatres were burned before they were entirely finished or opened to the public; seventy were burned during the first five years after they had been built; thirty-eight were burned from the sixth to the tenth year of their existence; forty-five from the eleventh to the twentieth; twenty-seven from the twenty-first to the thirtieth; twelve from the thirty-first to the fortieth; twenty from the forty-first to the fiftieth; seventeen from the fifty-first to the sixtieth; seven from sixty-first to eightieth; eight from the eighty-first to the one hundredth, and three after the hundredth year of existence. From this table, which gives the longevity (if this expression may be allowed) of two hundred and fifty-two theatres, of which there are authentic accounts, may be seen that in the first five years nearly one-fourth were destroyed, while only three reached the age of one hundred years.

There is, perhaps, no fact which illustrates to us the frequency with which these fires occur so clearly as the repetition of these catastrophes at the same theatre. The following is a list of theatres which were three times totally destroyed by fire: Her Majesty's, London; Drury Lane, London; Covent Garden, London; the Emperial Opera House, Moscow; Barnum's Theatre and Museum, New York; the Royal Theatre, Glasgow; the City Theatre, Namur; the Teatro Sao Pedro, Rio.

The following is a list of theatres destroyed four times; Astley's Amphitheatre, London; the Grand Opera, Paris; the City Theatre, Brunn; the National Theatre, Washington; the Bowery Theatre, of New York, leading the list, it having been five times totally destroyed by fire in less than forty years.

There is no more vicious argument than that which is frequently made, that it is unnecessary to improve theatres in our country, as they are much superior to those of Europe; lengthy arguments of this sort generally ending with the statement, that fewer theatres are destroyed by fire in the United States than any other country. To dispel such ideas from the public mind, your committee quotes the statistical comparison from the records of Foelsch and Hexamer, with the following astonishing result.

In grouping the six hundred and sixteen theatre-fires, which have been recorded according to the countries in which they occurred, we have the following:

In the United States	188
In Great Britain	87
In France	73
In Germany	53
In Italy	50
In Austria	33
In Russia	28
In Spain	21

All other smaller European States, fifty-six; all the other smaller non-European States, twenty-seven.

Your committee did not wish to make a report until it had thoroughly considered *how* the great number of fires at theatres, which is yearly increasing could be lessened, by the introduction of proper precautions; and by what means places where thousands congregate, not by necessity, but for pleasure, could be made entirely safe.

The consideration of the subject was taken up in the following order: The hazards of, (1) artificial light; (2) heating apparatus; (3) fire-works; (4) the use of paper wads in guns, and (5) the situation of the necessary workshops, paint lofts, spontaneous combustion of waste, etc.

After proper consideration of these subjects, your committee next studied methods for the improvement of theatres in regard to public safety, studying closely (1) the improvement of exits; (2) the division of the stage and rooms belonging thereto from the auditorium;

(3) the opening of doors; (4) safety systems of lighting, heating, ventilation, etc.

The greatest number of fires are caused by the paraphernalia of illumination. The danger of coal-oil, which is much used in our country and western theatres as an illuminating agent, is self-evident, but the hazards of gas, which but within a few years was the safest material at our command, are not so well understood. Besides the dangers of leakage and explosions, we have, in the case of gas illumination, hundreds of *flames* spread throughout a building, each forming a dangerous sphere around itself. Although the last named dangers can and should be lessened by proper precautions, such as wire baskets and shields over the flames, still, when we consider the close proximity of the border lights to combustible gauzes and canvas, and ponder on the hazards of temporary illuminating effects, where jets are fed through rubber hose which must be removed during change of scene, we must ask is there no other method of illuminating by which equally good artistic effects may be produced, and which at the same time will lessen or entirely do away with the hazards of the present system? Fortunately means are now at hand. By the labors of eminent electricians, we have at our disposal an agent by which the same, if not more brilliant, effects than those of gas can be produced, while doing away with the dangers of gas, the lamps themselves being absolutely safe. The finest piece of gauze might lie on one of these lamps without being harmed. At the same time the oppressive heat and deleterious products of the combustion of gas are done away with.

Your committee does not deem it necessary to describe the systems of "Incandescent Electric Lighting," the introduction of which would undoubtedly be one of the most necessary reforms of our present theatre system.

Your committee does not think that the arc light could be introduced to advantage in theatres, except in conjunction with reflectors so as to increase the brilliancy of the incandescent lamps. The disadvantages of all arc systems would be (1) their unsteadiness; (2) the color of the rays which would, as actors say, "bring out the paint," and by the want of warmth be disagreeable to audiences. The immense advantages of electric incandescent lighting, assisted by reflected arc lights over that of gas is, that it would do away with (1) the dangers from leakage and explosions of gas; (2) the oppressive heat of the numerous gas flames, which dries out the woodwork, canvass, and ropes of

the rigging loft, like tinder; (3) the fading of metallic colors caused by the products of gas combustion; (4) the very expensive processes of ventilation, which frequently do not give a sufficient supply of fresh air, may be greatly simplified as it is the great number of gas flames consuming more oxygen than the audiences do, which produces the "closeness" of theatres, and (5 and lastly) the fire hazard from contact with the light, as the glowing parts with the incandescent lights are hermetically sealed inside of a glass globe. Your committee is fully aware of the fire hazards of the electric light, but the incandescent lights (and especially our American systems) are, through the efforts of different committees, and foremost by that of the "New York Board of Fire-underwriters," so well supplied with safety "cut-outs" and "catches," and the erection of electric systems in the principal American cities is so well looked after by the special inspectors of the "Boards," that these dangers are reduced to a minimum. The practicability of electric light for the illumination of theatres, has been illustrated in the Savoy Theatre of London, which has for over a year been illuminated with electric light, proving it to be "a perfect artistic success."

Your committee has received the following letter from the management of the Savoy Theatre:

"In reply to your inquiries (1) The electric light is a perfect artistic success. (2) It costs, at present, about twice as much as gas in England, but the proposition here would, no doubt, be much less, as gas is much dearer than in England. Ultimately, no doubt, the cost in England will be the same.

Yours, faithfully,

R. Doyly Carte."

Theatres should be heated by steam or hot water systems. Stoves and heaters are objectionable. Where heaters are used, one-fifth of the registers should be so arranged that they cannot be closed, as many fires have been caused by overheated hot air pipes, in cases where all registers have been closed and the hot air could not escape. All register openings should be closed by fine wire netting to prevent combustible particles dropping into hot-air flues.

The only manner in which the dangers of fireworks may be lessened is by "*impregnating*" all scenery and gauze by approved processes. Your committee has for the past six months experimented with all ascertainable processes of impregnation. A process which your committee has found to be deserving of entire public confidence is that of Dr. J. Pafen, of Frankfort, Germany, which has been introduced to great extent; of its many commendable properties the following have

been certified on inquiry. The material may be used on scenery which has been painted upon, without destroying or injuring the colors; scenery which is impregnated in this manner does not, on being used, fill the air with a fine dust, deleterious to actors and singers, which was found to be a most disagreeable feature in other processes.

Your committee, at its request through the kindness of Messrs. Mertz and Schaede, received the following testimonial:

Frankfort-on-the-Main, August 2, 1882.

We herewith certify, on request of Messrs. Gustav Schaede and C. Rudolph Mertz, who have purchased the sole right to impregnate combustible substances for North and South America from Dr. Pafen, of this city, that after one year's use the following results have been obtained:

1st. The objects impregnated have proved, even after considerable length of use, to be perfectly incombustible.

2d. This quality has not been diminished by use in the least, as we have ascertained by repeated tests.

3d. The fabrics and colors have not suffered by the impregnation.

4th. No injurious effect of any kind have been observed to occur by Dr. Pafen's method on the voices of the singers and actors.

C. Rudolph,
Engineer of the Opera House.
Magnus Proesler,
Inspector of the Opera House.

Satisfactory results have also been obtained by the processes of Gautsch, Judlin, by sulphate of ammonia, and by silica deposited into the fibres by precipitation.

Besides impregnating the scenery, the woodwork should be covered with some fire-proof paint. Your committee experimented with all the solutions they could ascertain, and had most satisfactory results from "asbestos paint," and especially from the so-called asbestos concrete.

Paper wads in guns and pistols, by settling on gauze or canvas while still glowing, have repeatedly caused theatre fires. Your committee believes that the practice of using wads of hair, would overcome this hazard. Quick burning powder is recommended for theatre firearms; since the sole purpose is to make a noise, and slow burning powders, especially *soda powders*, being deliquescent; such grains of powder will, when ignited, be carried in a burning condition considerable distances from the muzzle of the gun, thus readily igniting combustible objects.

The workshops and paint loft should be located outside of the

theatre proper, and should communicate with the stage only by double iron lined doors with stone sills.

Your committee has thought best to bring all minor matters into a series of recommendations, but before proceeding to give them must mention that there are important automatic devices for opening a smoke flue above the stage, lowering the fireproof curtain, and sending an alarm, none of which have, however, been introduced into the United States.

Your committee have sought much to find a good fire proof drop curtain.

The results obtained of woven asbestos *cloth* were most satisfactory, and smaller experiments, as well as one performed on a large scale at the Brooklyn Navy Yard, convinced your committee that it makes an excellent fire curtain.

Transparent wire drop curtains are objectionable, as in case of fire they allow smoke to pass through them, and by not cutting off the view of the fire from the auditorium, increase the panic.

Your committee does not think that the curtain used at the new Opera House at Geneva is much better.

This consists of a wire screen of very fine meshes, like the material employed for a Davy's safety lamp, they being covered on both sides with a coarser wire netting. Curtains of this kind have not yet stood the "fire test." Your committee believes that in case of fire it will not be of better service than the ordinary wire curtain.

The curtain recently constructed for the new theatre "des Celestins," at Lyons, is constructed on a similar principle to the above, and is hemmed in by a border of sheet iron two metres broad. Although this will somewhat reduce some objections, yet it is not a commendable curtain.

At Lyons, Lille, Toulon, and for the new "Theatre des Arts," at Rouen, curtains of iron have been introduced. These consist of a number of horizontal slats put together like venetian window blinds, and are raised and lowered by hydraulic apparatus. Whether such curtains will in the course of time prove themselves successful, is still problematical. The two great objections which your committee sees in these curtains is their tendency to rust, and the ease with which they would warp at large differences of temperature, as in case of fire.

Sliding curtains of corrugated sheet iron have stood best in case of

fire. They have been employed with great success at the Hof Theatre, Dresden; Central Halle, Hamburg; Hof and National Theatre, Munich; New Opera House, Frankfort-on-the-Main; Wallmer and Friedrich-wilhelmstadter, Belle-Alliance Walhalla, and Central Theatres at Berlin; Concordia Theatre, Hamburg, and others.

Your committee cannot too strongly bring out the fact that the regulating apparatus of the curtain should be on the stage; and not, as was the case at Vienna, in the rigging loft, a place which in case of fire immediately becomes inaccessible. If the apparatus is one which is set in motion by a crank, the handle should be so fixed that it cannot be removed, or it will in most cases be taken off in order to gain room, be stowed away somewhere, and will at the moment of danger be missing.

Your committee heartily endorses the action of the authorities of Vienna, who now require a man posted at the safety curtain lowering apparatus during all performances.

Your committee has had no chance of testing the patent curtain of Carl Pfaff, but from the report of the special committee of the "Oesterreichischen Ingenieur und Architekten-Verein," has been convinced that it is one, if not the most meritorious fire curtain known up to this time; the above committee after careful tests gave the following report of its properties: (1) That a curtain constructed on this principle could be used daily with surety and with a small amount of trouble. (2) That they were satisfied of the durability of the proposed invention. (3) That in case of fire the invention would work with rapidity. (4) That it would give the auditorium the necessary protection. (5) That it would restrict the fire to the stage.

Your committee begs leave to submit the following recommendations, many of which are already law in several European States:

First. All corridors should increase in width from the theatre to the open air.

Second. All extra exits (fire corridors) should be marked as such in large, bold letters; should be lighted by oil lamps (not petroleum products; sperm or lard oil is recommended), and should be unbarred from the opening of the theatre until it is closed. Before the close of every performance they should be opened, that the extra exits may become known to the public.

Third. All doors should open outwards.

Fourth. Bannisters or railings should be fastened to the walls of all

stairways; they should be fitted into grooves in the wall; enough room being left between the rail and the groove to allow hands to slide freely on the rail.

Fifth. Long rows of seats should NOT be permitted. Rows should be cut by an aisle at least at every twenty feet.

Sixth. Movable seats should not be allowed. Seats should be tightly screwed to the floor. Fixed chairs with a spring attachment, which throws back the seats when not occupied, are strongly recommended.

Seventh. No scenery, properties, materials, or impediments of any description should be allowed to remain in corridors.

Eighth. The stage should be divided from the auditorium by a fire-proof drop curtain. Transparent wire curtains should not be used for this purpose.

Ninth. The fire-proof drop curtain should be kept down at all times except during rehearsals and performances; after which it should be immediately let down, and not raised until fifteen minutes before the beginning of the next performance.

Tenth. Doors and openings in the proscenium wall should be with stone sills, iron lined (on both sides), and should be self-closing.

Eleventh. The system of lighting the stage should be separated from that of lighting the auditorium; each should have a distinct feed-pipe or circuit.

Twelfth. Gas flames should (without exception) be covered by wire baskets. These baskets are to be made sufficiently large, so that the wire may never be heated to a greater temperature than 250°.

Thirteenth. Border and foot lights should be lighted by electricity, *not with an open light.*

Fourteenth. Every theatre should be supplied with a sufficient number of fire hydrants, with hose and nozzle attached ready for instant use, and not removable.

Fifteenth. A large reservoir, holding at least eight thousand gallons, should be placed over the auditorium ceiling; kept at all times full of water, connecting with the stand-pipes, and not allowed to freeze.

Sixteenth. A sufficient number of fire buckets (used in case of fire only) kept always filled should be distributed conspicuously over the premises.

Seventeenth. Every theatre should have a number (varying with the size of the theatre) of fireman.

Eighteenth. In order to keep control of the various theatres, a theatre inspector should be appointed in each town, who should have full power to enter every theatre at any moment, and whose duty it should be to see that these or other suggestions made law by an act of legislature, are faithfully carried out.

Nineteenth. The testing of all gas pipes, hydrants, and fire appliances should be performed at least four times a year, and oftener if the theatre inspector requires.

Twentieth. Every theatre should be connected with the nearest fire station by numerous electric alarms, most of which should be automatic.

Twenty-first. The theatre should be patroled at day and night, by watchmen, who should be controlled by watch-clocks, distributed over various parts of the building.

Twenty-second. No smoking should be allowed in the theatre, except where required on the stage in the representation of plays.

Twenty-third. No swinging gas brackets should be allowed in any part of the theatre.

Twenty-fourth. Woodwork which is within eighteen inches of a gas flame should be covered with sheet iron or tin, but in such a manner that air may circulate between the iron and the wood.

Twenty-fifth. Border lights should be so enclosed that no part of the enclosing body may be heated to a higher temperature than 250° Fahrenheit.

Twenty-sixth. Where heaters are employed the registers should be covered by fine wire netting, and at least one-fifth of the registers should be so arranged that they cannot be closed.

Twenty-seventh. Scenery and other stage supplies should not be stored on the stage, but in a separate *fire-proof* dock.

Twenty-eighth. No more scenery should be put upon the stage than is necessary for, at most, two performances.

Twenty-ninth. The use of fireworks, Roman candles, red fires, etc., should only be permitted when it has been shown to the "*Theatre Inspectors*" satisfaction that the scenery and gauzes have been impregnated by proper substances, and that the woodwork has been covered by some satisfactory solution.

Thirtieth. Wads of pistols and guns should be of hair only (not paper or cotton).

Thirty-first. If straw, hay or any other easily inflammable substance

be required in a scene, it should be removed to a fire-proof place immediately after the scene in which it is used.

Thirty-second. A large smoke flue should be provided above the stage. Automatic devices are recommended.

Thirty-third. That the public itself may have control in this matter, a complaint book should in every theatre be laid open to the public, where any individual may enter any faults of construction or arrangement which he has noticed. This book should not be the property of the proprietor of the theatre, but should belong to the "Theatre Inspector," the Fire Marshal, and Building Inspector of the city.

Thirty-fourth. Numerous permanent iron ladders should be fixed on the outside of the building, so that the firemen may readily enter the theatre while the corridors are still filled by the departing audience.

Thirty-fifth. Oil lamps should be cleaned and trimmed in a separate lamp and oil room, where, also, the oil should be stored. Oily rags and waste should be kept in small quantities only, and in iron boxes closed by an iron lid, and standing on brick, or other fire-proof substance, and as soon as they accumulate should be burnt.

Thirty-sixth. The workshops and paint loft should be outside of the stage building.

Thirty-seventh. Automatic sprinklers and steam jets should be placed over and on the stage. (The theatres of Boston are required by law to protect the stage by a system of automatic sprinklers. In November, 1882, a fire was extinguished at the Providence Theatre Comique, during a play, by automatic sprinklers, with so little injury, even to the scenery, that the performance was not stopped).

Thirty-eighth. Ground plans of the auditorium, giving a clear idea of the building, corridors, stairways, etc., should be prominently located in the halls, and should be printed on the back of programmes.

Your committee is well aware of, and have followed with sympathy and hearty approval the labors of the Asphaleia, a society of prominent German and Austrian technologists, who have made it their purpose to construct a theatre up to the requirements of our time, which should not only fulfil all technical qualities, but bring the theatre to an artistic perfection which it now lacks. This work your committee thinks they have almost accomplished, and all new theatres should be built according to their suggestions.

Your committee has tried to correct objectionable and suggest better features in theatres as they now exist, and has especially tried to make suggestions in reference to American theatres.

Your committee at first intended to inspect and report on all theatres of Philadelphia, as was done by a similar committee of the Citizens' Association of Chicago, but on due consideration doubted whether it was vested with sufficient power by the Institute to carry this plan into effect.

Your committee in closing its report cannot help referring to two most necessary factors in reforming our theatres. (1) The education of the public on this subject by popular lectures, articles and papers: and (2) the co-operation of prominent mechanics and scientists. While the mechanical engineer of to-day, through the arm of a child, moves enormous loads by his hydraulic cranes, the numerous hoisting apparatuses of the stage are of a truly pitiable simplicity.

The problem of building theatres properly, is eminently one of the mechanical engineer, and will never be solved if the technical resources of our age are not taken into account, and brought to bear on the question.

C. JOHN HEXAMER, C. E.
THOMAS SHAW, M. E.
HENRY R. HEYL.

MINORITY REPORT.

Philadelphia, April 18th, 1883.

The undersigned heartily approves all of the foregoing except the thirty-second recommendation, page 438, for a smoke flue above the stage, and that portion on the same page which refers to the work of the Asphaleia, concerning which he has no personal knowledge. He considers a smoke flue above the stage as in the highest degree dangerous, and calculated to increase the draft and strengthen the flames, producing a general conflagration instead of a local blaze.

ROBERT GRIMSHAW.

Imitation Caoutchouc.—Dankworth and Landers, of St. Petersburg, have invented a composition which is elastic, tough, waterproof and insulating, and which is applicable to nearly all the purposes for which India rubber is used. It is composed of a mixture of wood and coal tar, linseed oil, ozokerit, spermaceti and sulphur, which are thoroughly mixed and heated for a long time, in large vessels, by means of superheated steam.—*Ackermann's Gewerbezeit'g.* C.

THE SECOND LAW OF THERMO-DYNAMICS.

By H. T. Eddy, Ph.D., University of Cincinnati.

Professor De Volson Wood has, in the May number of this Journal, attempted to show the geometric and mechanical impossibility of the process I have suggested for interfering with the ordinary exchanges of radiant heat between bodies. His mistake is in substituting a mill of his own invention for mine, and different from mine, and then showing that his mill will not work, as it certainly will not. In constructing his mill he has evidently placed his reflectors *c*, at right angles to the path of the ray. But I have made no such assumption in regard to the proposed position of my reflectors, for I say on the first page of my original article: "Let the surface of *c* which faces *b* be perfectly reflecting, and let the parts between its apertures be either concave or a series of inclined planes so directed that each of the projectiles will pass back through one of the apertures in *b*." Is it denied that they can be so directed? They certainly can be so directed, even though "the apertures are so placed that *a*, *c*, *b*, are upon one (and the same) straight line," as I have stated them to be, instead of being upon different lines, as Professor Wood has placed them.

That this inclined position of the reflectors is contemplated all through my paper is seen also from a sentence on the page next to the last, where I say that the "vanes (of the screen *c*) may be so inclined as to return radiations coming from *B* partly to apertures in front of those from which they emanated and partly to those behind." In fact, the very proof on which Professor Wood relies to show that his mill will not work, demonstrates beyond doubt that my mill will work, for the part of his mill which stops radiations from *A* is just where I have an aperture to allow them to pass.

Change of Volume in Galvanizing.—E. Bouty has found by recent observations that the variations of volume in galvanic deposits, which exercise a pressure upon the moulds, and the Peltier phenomenon at the surfaces of contact, are mutually connected. He finds a certain intensity of current, which he calls the neutral point of temperature. In all higher intensities the electrode heats, and in lower intensities it cools, during the process of deposition.—*Comptes Rendus.*

ON THE PRESENT CONDITION OF THE SODA INDUSTRY.

By WALTER WELDON, F.R.S.

[Abstract of a paper read before the Society of Chemical Industry, January 8, 1883.]

About a fortnight ago the *Times* spoke of the manufacture of soda by the Leblanc process as being, "to some extent, a dying industry." Although I hope to show this evening ground for believing that that industry is not going to die just yet, it has certainly for some time past been in a condition by no means satisfactory to the greater number of those whose capital is engaged in it. For manufacturers of soda, by the Leblanc process, recent years have been years in very many cases of loss, and in not a few cases, of disaster. Of twenty-five alkali works which were in operation in the neighborhood of Newcastle-on-Tyne a very few years ago, only thirteen are in operation now; and of the other twelve* not fewer than eight have been actually dismantled, in utter dispair of its ever again being possible to manufacture soda in them by the Leblanc process, except at an absolute loss. The alkali-making districts of Lancashire have advantages over the Newcastle district in respect alike of the price of salt, of facilities for supplying the American market, and of nearness to certain of the great English centres of soda consumption; but, nevertheless, even in Lancashire some seven or eight alkali works are standing idle, and but few of the others are working up to their full capacity. In Belgium, where there are five or six works which formerly made soda by the Leblanc process, matters are even worse, since in that country the manufacture of Leblanc soda has entirely ceased. The only other European countries in which the soda industry as yet exists are France, Germany and Austria.

From information kindly supplied to me by manufacturers in all the countries in which the soda industry is practised, I have been enabled to draw up a statement of the present total soda production of the world, and of the proportions in which that production is divided between the Leblanc process and the ammonia process. In drawing

* The quantity of salt decomposed in these twelve works was about 67,000 tons a year. The quantity decomposed in the thirteen works still in operation is about 220,000 tons a year.

up the following table, I have converted all the figures supplied to me, alike those for soda ash, those for crystals, those for caustic soda, those for bicarbonate, and those for black ash sold as such, into terms of pure Na_2CO_3:

PRESENT SODA PRODUCTION OF THE WORLD.

	Leblanc soda.	Ammonia soda.	Totals.	Ammonia soda per cent. of total soda.
Great Britain.....	380,000	52,000	432,000	12·0
France.....	70,000	57,125	127,125	44·9
Germany	56,500	44,000	100,500	43·8
Austria.....	39,000	1,000	40,000	2·5
Belgium.....	.....	8,000	8,000	100·0
United States.....	.....	1,100	1,100	100·0
Total.....	545,500	163,225	708,725	23·0

This table shows that the total quantity of soda now being manufactured annually is nearly 710,000 tons, and that of this quantity more than 163,000 tons are produced by the ammonia process.

Although it is now more than forty-seven years since the ammonia process was first proposed by Dyer and Hemming, it is less than seventeen years since that process was first realized industrially. As an industrial process, capable of being worked continuously and with satisfactory commercial results, the ammonia process dates only from 1866, being the year in which M. Ernest Solvay, of Brussels, began to produce ammonia soda at works which he had established for the purpose at Couillet, near Charleroi. M. Solvay has now two other ammonia soda works in operation,—one in France, at Varangeville-Dombasle, near Nancy, and one in South Germany, at Whylen, in the Grand Duchy of Baden,—and by his courtesy I am enabled to place before you the following statement of the quantities of ammonia soda which he has manufactured in each complete twelve months from May 1st, 1866:

	Tons.	
1866–67	179	Couillet only.
1867–68	465	
1868–69	719	
1869–70	940	
1870–71	1,862	
1871–72	2,805	
1872–73	3,423	
1873–74	3,980	
1874–75	4,678	
1875–76	5,768	Couillet and Dombasle.
1876–77	11,579	
1877–78	19,247	
1878–79	25,023	
1879–80	32,326	
1880–81	42,069	Couillet, Dombasle, and Wyhlen.
1881–82	53,400	

These figures come down to the 30th April last. Since that date, however, M. Solvay has increased his production by nearly 60 tons per day, or 21,000 tons per annum, so that he is now making ammonia soda at the rate of nearly 75,000 tons a year. He is thus making ammonia soda on nearly three times the scale on which he was making it four years ago, and on nearly twice the scale on which he was making it only two years ago. In France and Germany, M. Solvay's great success has tempted other manufacturers into the field, and although none of them are as yet large makers, their total production amounts to fully 35,000 tons per annum, raising the total Continental production of ammonia soda to about 110,000 tons per annum, out of a total production by both processes of 275,000 tons. Of the total soda now being made on the Continent, therefore, about forty per cent. is being made by the ammonia process. While the quantity of Leblanc soda made in France has neither increased nor diminished during the last few years, the quantity of Leblanc soda made in Germany and Austria has increased by several times the quantity formerly made in Belgium, so that not only these 110,000 tons of ammonia soda per annum, but also fully 25,000 tons per annum of Leblanc soda, have been added, comparatively recently, to the soda production of the Continent; going partly to supply increased consumption, but largely to diminish importation from England. And of this vast increase in the Continental production of soda, four-fifths of which increase is due to the ammonia process, two-thirds have

sprung into existence within the last five years, and a large part of those two-thirds within only two years.

In England, within the last two years, the production of ammonia soda has been nearly trebled. The ammonia process is practised in this country as yet only by one firm. In 1873 it was not in operation in this country at all. In that year our Honorary Foreign Secretary, Mr. Ludwig Mond, arranged with M. Solvay for the right to work under his patents in this country, and in the following year, in conjunction with Mr. J. T. Brunner, Mr. Mond began to make ammonia soda at Winnington, near Northwich. Messrs. Brunner and Mond began on a very modest scale, their production in 1875 not exceeding 2,500 tons; but in 1878 their production rose to 10,000 tons; in 1880 it was 18,800 tons; and it is now at the rate of not less than 52,000 tons per annum, or at very nearly three times the rate of only two years ago.

The competition of the ammonia process with the Leblanc process has thus attained its present degree of seriousness only very recently indeed. It has come upon the makers of Leblanc soda almost like a thunderbolt out of a clear sky.

And, serious as that competition is already, it is about to become even more serious still. Not only is it to be expected of the existing ammonia soda works that those of them which have recently so greatly increased their production, and that those of them which have more recently started will grow as the older ammonia soda works are being built. M. Solvay, who has already, as I have said, a work in operation in South Germany, besides his French and Belgian works, and who is already by far the largest soda maker in the world, will soon have a work in operation in North Germany also, at Bernburg, near Stassfurt; and he is now, moreover, erecting a work in Russia, and also a work in the United States, and is on the point of commencing the erection of a work in Austria, so that by-and-by he will be making soda in no fewer than seven distinct works, in six different countries. In addition to all this, a large work to make ammonia soda, not on M. Solvay's system, but on a system modified from that practised at Dieuze, is being erected near Stassfurt by the Company of Buckau; an ammonia soda work is building, and will be started in the spring, at Favorznow, near Cracow; and one is about to be built at Siebenburgen, in Transylvania, not to speak of the intention of Messrs. Bell Brothers to build an ammonia soda work at Middlesbrough. The

new works which are thus in course of construction, and some of which are nearly completed, will throw on the market more ammonia soda, to the extent of not less, from the commencement, than from 65,000 to 70,000 tons a year.* For Leblanc soda makers it is thus as though ammonia soda had latterly rained from the skies during two days out of every three, and the shower were now on the point of becoming continuous.

While face to face with so serious an amount of competition, actual and imminent, on the part of the ammonia process, the Leblanc process pure and simple is now further threatened with what is surely the "most unkindest cut of all," namely, with competition from the Leblanc process itself, combined with the extraction of copper from Spanish pyrites.

To explain how this has come about, I must remind you that the sulphuric acid used in the Leblanc process is now invariably manufactured from the sulphur of pyrites; that the pyrites used in this

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* As no complete list of ammonia-soda works has yet been published, it may be interesting here to give one. The following list includes all the works now actually in operation:

ENGLAND:
Winnington,
Sandbach.

GERMANY:
Wyhlen,
Duisburg,
Inowrazlaw,
Grevenberg,
Dieuze,
Trotha,
Heilbronn,
Nürnberg,
Rothenfelde.

FRANCE:
Dombasle,
Giraud,
Sorgues,
St. Denis,
Lille.

BELGIUM:
Couillet.

AUSTRIA:
Boszko.

UNITED STATES:
Bay City.

Ammonia-soda works are now being built in the following localities:

AUSTRIA:
Favorznow,
Siebenburgen.
?

RUSSIA:
Berenski.

GERMANY:
Stassfurt,
Bernburg.

UNITED STATES:
Syracuse.

There is a reason why the locality of the works about to be built by M. Solvay, in Austria, may not yet be published.

country is now almost exclusively either Spanish or Portuguese pyrites, containing two or three per cent. of copper and very small quantities of silver and gold; that after most of the sulphur has been burnt off from the pyrites, as the first step in the manufacture of sulphuric acid, the residual "burnt ore," or "pyrites cinders," as it is called, is treated by the wet way for the extraction from it of copper, and in most cases now of gold and silver also;* and that what remains when these have been extracted is an almost pure oxide of iron, which finds a ready sale for use for various purposes in connection with the manufacture of iron and steel. The supply of this cupreous pyrites is for the most part monopolized by three great companies,—the Tharsis Company, the Rio Tinto Company, and Messrs. Mason and Barry. These companies not only supply nearly the whole of the pyrites used in the manufacture of sulphuric acid in England, but the Rio Tinto Company also supplies annually some 60,000 tons of pyrites to Germany, and is also beginning to send pyrites into Austria. None of the three companies, however, has been able to sell an ounce of pyrites in France.

The reason of this is that in France itself there are two large deposits of pyrites, both belonging to soda makers: one belonging to the Compagnie de St. Gobain and the other to MM. Pechiney et Cie. Each of these companies itself uses its own pyrites; and the former of them supplies with pyrites the greater number of the other alkali makers in the North of France, while the latter supplies with pyrites all the other alkali makers of the South of France. It has obviously been impossible to sell Spanish pyrites to either of the two great soda making firms, each of which thus has pyrites, and by no means dear pyrites, of its own, and each of which is a large seller of pyrites to other soda makers; and the other soda makers, for the most part, have been precluded from even considering the question of changing to Spanish pyrites, if only by reason of the French habit of contracting for the supply of raw materials over very long periods. A French manufacturer's contract for raw materials is generally a contract for fifteen years; and most of the French soda makers are now obtaining

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* A German analysis of Rio Tinto pyrites gives the following results per 1,000 kilos:

495 kilos. sulphur.	26 grammes silver.
430 kilos. iron.	180 miligrammes gold.
30 kilos. copper.	150 grammes bismuth.
10 kilos. lead.	

their pyrites under contracts which have yet a considerable time to run.

Under these circumstances the Rio Tinto Company has taken a remarkable step. To understand the motive to this step it must be borne in mind that while French pyrites does not contain copper, and so has scarcely any value beyond that of the sulphur which it contains, Spanish pyrites has a considerable value in addition to its sulphur value. While the value of Spanish pyrites for the sulphur in it is equal to that of the best non-cupreous pyrites, its value for copper is greater than its value for sulphur, and, not to speak of its value as regards precious metals, it has also a considerable value for its iron. In this country, the cinders left after as much as possible of the sulphur of non-cupreous pyrites has been burnt off, are considered to have no value at all; and even in France, where the import duty on cast iron is greater than the present price of Glasgow pigs, and where all forms of iron are therefore appreciably more valuable than in this country, the cinders of non-cupreous pyrites are not worth more than 3f. per ton. They always contain sulphur, and sometimes contain phosphorus. The cinders of cupreous pyrites, before treatment for the extraction of copper from them, also contain sulphur, and in larger quantity than the cinders of non-cupreous pyrites; but the treatment to which they are subjected for the extraction of their copper removes the whole of their sulphur, and also the whole of their phosphorus, if they have contained any, leaving a residual oxide of iron of great purity. This residual oxide, or "purple ore," as it is called, now sells in this country for 12s. per ton, and in France it would doubtless command a higher price.

Now, in this country a state of things has grown up under which the manufacture of Leblanc soda derive no advantage from the value for copper and iron of the pyrites which they employ. The treatment of the cinders of the cupreous pyrites has become in this country a separate industry, practised only in a few instances by alkali makers themselves, but practised for the most part by companies or individuals who do not make soda, but who either buy from soda makers the cinders or pyrites of which the soda makers have bought both values, the copper value as well as the sulphur value, or themselves buy both values, selling only the sulphur value to the soda makers, or else buy direct from the pyrite sellers the copper value only; the pyrite sellers in such cases selling the copper value of their pyrites to one purchaser

and its sulphur value to another. It is an industry which yields fair commercial profits, so that soda makers may be incurring actual loss, while those who deal with the cinders of the pyrites from which the soda makers have burnt off sulphur are at least making a living. And while the treatment of the cinders of Spanish pyrites is fairly profitable in this country, the greater value of iron and iron ores there than here would doubtless render it more profitable in France. It is true that coal is more costly in France than in England; but the quantity of coal required for treating pyrite cinders is not great.

The course, then, which the Rio Tinto Company is taking is this. Unable to sell its pyrites to the French Leblanc soda makers, it has determined that the Leblanc soda made in France, or at least a large part of it, shall nevertheless be made by means of Rio Tinto pyrites, and to this end it has promoted a subsidiary company, "La Compagnie d'Exploitation des Minerais de Rio Tinto," which company is to make Leblanc soda in France and elsewhere, relying for its profits neither on soda nor on chlorine, but on copper and oxide of iron. For this company soda and chlorine will be simply by-products, which it will be glad to sell at a profit, if that may be, but which, if that may not be, it will be content to sell at the bare cost of manufacturing them. It will manufacture them only for the sake of converting Rio Tinto pyrites into pyrite cinders.

This new company proposes to operate upon an enormous scale. It has a capital of £1,200,000 sterling, of which one-half is already paid up, and there is talk of its building in France no fewer than five great works; one of which, designed and to be managed by Englishmen, it has already commenced in the neighborhood of Marseilles. The result cannot but be grave for the existing French Leblanc soda makers, and must inevitably affect the makers, both of Leblanc soda and of ammonia soda, in this country also.

Moreover, this new company will not confine its operations to France. Not only will it take Spanish pyrites to the United States, and there make sulphuric acid, extract copper, and obtain "purple ore," large quantities of which at present go from England to America, but it will also build a large soda-making and copper-extracting works, which will certainly affect the English alkali trade, in the neighborhood of Antwerp. The Leblanc process will thus be reintroduced into Belgium, not as a substantive process, but simply as a part of a combination of processes for the utilization of cupreous pyrites.

To such complexion has the Leblanc process come at last. Originally, soda was its only commercial product, the hydrochloric acid produced during the first stage of it being turned to no account. In time a demand grew up for chlorine, that hydrochloric acid began to be utilized, and the manufacturers of Leblanc soda now sent into the market two products, by each of which they gained profits. Then their soda ceased to be profitable, and became a kind of by-product, which they continued to make only because they could not otherwise make chlorine. Now, Leblanc soda gives no profit at all, and chlorine none to speak of; and both have come to be regarded as secondary products, to be made only incidentally, and only because making them is essential to the application to certain ores of the wet method of extracting copper.

Returning to the ammonia process, when that process first began to threaten them, the makers of Leblanc soda comforted themselves by two considerations; one of which was that the ammonia process must itself tend to check its own extension, by reason of the loss of ammonia inseparable from that process so increasing the demand for ammonia as to materially raise the price of that body. They knew that the constantly-increasing demand for ammonia for the purposes for which it was already employed had doubled its price within twenty years; and they thought that every further extension of the ammonia soda process must still further increase the market value of ammonia, until at length the ammonia process would cease to have any advantage over the Leblanc process. So far, however, from that anticipation having been realized, despite the immense extension which the ammonia soda process has recently undergone, the price of ammonia is now beginning to fall. The delusion that it was impossible to collect the ammonia given off from coke ovens without spoiling the coke is at last giving way before accomplished facts. Ammonia is now being obtained commercially, not only from coke ovens, but also from another source, wholly unforeseen and unexpected; and the time, moreover, seems at last to have dawned when there will be collected and utilized as ammonia at least a portion of nitrogen of nearly all the fuel burnt either for industrial or for domestic purposes. In France ammonia has been collected from coke ovens for a number of years past.

Some months ago, a member of the firm of William Baird & Co., who happens to be also a director of a gas work, Mr. William Ferrie, was struck by the idea that the methods employed for separating

ammonia and tar from crude illuminating gas might be used for separating the same bodies from the gases from blast furnaces in which raw coal is used; and although the volume of the gases from such furnaces, per ton of coal employed, is about thirteen times greater than that of the gases obtained by distilling the same kind of coal in retorts, is not less, that is to say, than 130,000 cubic feet, Mr. Ferrie's idea has been put into execution with complete success. From two of the sixteen blast furnaces at the Gartsherrie iron works ammonia and tar have been regularly collected for some months past, and the preparations are in progress for collecting them from the other fourteen blast furnaces there. The quantity of ammonia at present being obtained at Gartsherrie is the quantity corresponding to about 18 cwt. of ammonium sulphate per day, being at the rate of 20 lb. of ammonium sulphate per ton of coal consumed.

Each of the one hundred and twenty Scotch blast furnaces consumes, on an average, fifty tons of coal per twenty-four hours. The total quantity of coal consumed in them per annum is thus $50 \times 120 \times 365 = 2{,}190{,}000$ tons. The quantity of ammonia yielded per ton of coal being, as I have said, the quantity corresponding to 20 lb. of ammonium sulphate, there can thus be obtained per annum from these one hundred and twenty blast furnaces a quantity of ammonia corresponding to nearly 20,000 tons of ammonium sulphate, worth, at the present selling price of that commodity, not less than £400,000.

Large, however, as is this quantity, it is only one-tenth of the further quantity which can be obtained from English coke ovens. The quantity of coal coked annually in England is not far short of 20,000,000 tons, and if Mr. Jameson's system were applied to the whole of our coke ovens, with the result of collecting, per ton of coal treated, the same quantity of ammonia as is obtained from the Gartsherrie blast furnaces, there would be obtained from this source per annum the quantity of ammonia corresponding to 180,000 tons of ammonium sulphate, at present worth more than three and a half millions sterling. Nor is even this all; for I shall have to speak in a moment of another possible, and I believe probable, source of ammonia, even more extensive still.

Now of the ammonia employed by the ammonia soda maker, he loses from one-fiftieth to one-fortieth part. As he has to employ from one and a half to one and three-quarter equivalents of ammonia for each equivalent of sodium carbonate finally obtained, we may take it

that he loses about one twenty-third of an equivalent of ammonia for each equivalent of sodium carbonate manufactured. In terms of ammonium sulphate, being the terms in which the loss of ammonia in the ammonia soda process is usually stated, this loss corresponds to about five and a half parts of ammonium sulphate per hundred parts of sodium carbonate produced. The total annual loss of ammonia in the manufacture of the 163,000 tons of ammonia soda now being produced per annum thus corresponds to just about 9,000 tons of ammonium sulphate. This is, no doubt, a large quantity of a commodity worth £20 per ton; but, in comparison with the extent of the new sources of ammonia which have just began to be turned to account, it is utterly insignificant. It is less than one-twentieth part of the quantity capable of being yielded by blast furnaces and coke ovens in Great Britain alone, and is a smaller fraction still of the quantity which, I believe, can be obtained from another source which has yet to be mentioned. We may therefore be quite certain that the progress of the ammonia soda process will not be hindered or limited by any difficulty as regards supply of ammonia.

The other consideration to which I referred as having given comfort to the makers of Leblanc soda, and which constituted indeed their chief ground of hope for salvation against the ammonia process, was that the world requires chlorine as well as soda, and that while the chlorine of the salt decomposed by the Leblanc process is yielded as hydrochloric acid, from which free chlorine can be obtained readily, the chlorine of the salt decomposed by the ammonia process is yielded as a somewhat dilute solution of calcium chloride. It was thought that the ammonia process would eventually even help the existing Leblanc soda makers, by preventing the further extension of the Leblanc process, and so restricting the production of hydrochloric acid, and thereby at length increasing the value of that body. The ammonia process, no doubt, would have produced that result, and would have produced it by this time, if the supply of hydrochloric acid in this country had not been already so largely in excess of the demand for chlorine products. That demand is always becoming larger, and within the last few years the production of hydrochloric acid has appreciably diminished; but in this country the constantly-increasing stringency of legislative enactments with respect to river and air pollution has compelled so many producers of hydrochloric acid, who would have preferred to throw their acid away, to employ it

in the manufacture of chlorine, whether that manufacture were profitable or not, that the selling price of chlorine products has of late years been continually falling, until it is now at a point at which it barely pays their cost. No doubt if all the other conditions of the problem were to remain as at present, the demand for chlorine products would in time overtake the supply of hydrochloric acid in this country, as it has long since done on the Continent, and the manufacture of chlorine in England would so again become profitable. But the other conditions of the problem are not likely to remain stationary, and both M. Solvay and myself are doing our best to change them.

M. Solvay is proposing to manufacture hydrochloric acid from the residual calcium chloride of the ammonia process. I imagine that he is urged to that course, not merely by a desire to turn that calcium chloride to account, but also by a desire to avoid making too much nuisance. For it must not be supposed that even the ammonia process, when practised on a large scale, is free from nuisance. It certainly does not send into the air any noxious vapors, but it sends into the water courses very large quantities of calcium chloride, rarely accompanied by less, and often accompanied by much more, than an equivalent quantity of sodium chloride, and very apt to be accompanied also by both calcium carbonate and free lime. Neither calcium chloride nor sodium chloride will do much harm to a river, if sent into it in moderate quantities; but when it comes to sending into a comparatively small stream, far inland, two hundred and sixty tons of calcium and sodium chlorides per twenty-four hours, say about ten tons per hour, night and day, all the year through,—and M. Solvay must be doing something very like that at Dombasle,—the matter assumes quite another aspect. I am not myself an angler, but if I were, I do not think that I should seek for sport immediately below Dombasle.

Be all that however as it may, M. Solvay is now erecting at Dombasle apparatus for an industrial trial of a process for obtaining hydrochloric acid from calcium chloride, at which he has been working for many years. The process in question consists in first concentrating by evaporation the mixed solution of calcium and sodium chlorides which is the residual product of the ammonia process; then mixing the concentrated solution with clay, making the mixture into balls, and drying these balls; and then heating these balls to redness in a current of steam. This process certainly works, on condition that the temperature employed be sufficiently high, and that the quantity of steam used be

largely in excess of the quantity necessary to react upon the calcium chloride. As the resulting mixture of vapor of water and vapor of hydrochloric acid would otherwise give an extremely dilute aqueous acid, M. Solvay proposes to separate from it most of its vapor of water, before condensing its hydrochloric acid, by passing the mixture of the two vapors through a very strong solution of $CaCl_2$, which he finds will absorb most of the steam from such a mixture, allowing the HCl to pass on alone, so that it can afterwards be condensed in the usual way. All this is ingenious, but it can hardly be cheap. First, a solution containing only about eight per cent. of calcium chloride has to be evaporated, we may say to dryness; then the mixture of $CaCl_2$ and clay has to be maintained at a red heat for a considerable time, in a current of steam; and then the solution of calcium chloride used to separate steam from the resulting mixture of steam and HCl has to be prepared for use again by having all the water which it has absorbed evaporated off from it. To English manufacturers who have more hydrochloric acid than they can use, this process of M. Solvay's will seem little less than ridiculous; but one must remember that it is intended for countries in which the demand for hydrochloric acid exceeds the supply, and in which countries, moreover, chlorine products are protected by import duties. In such countries, one can quite conceive its being commercially practicable; in which case the exportation of chlorine products from England to the Continent is doomed. I ought to add that M. Solvay expects that the silico-aluminate of calcium which remains after the chlorine of his mixture of calcium chloride and clay has been driven off by steam will be useful as a cement, and will thus help to pay the cost of his hydrochloric acid.

The exportation of chlorine products from England to the Continent is, moreover, threatened in another way. The Continental manufacturers of Leblanc soda, unlike the English manufacturers of Leblanc soda, do not produce enough hydrochloric acid to meet the demand of their respective countries for that acid itself, and the products which are made from it. This is partly due to the production of ammonia soda, proportionately to the total production of soda, being so much greater in France and Germany than in this country, and partly to hydrochloric acid being required in those countries for industries which in this country do not exist. Large quantities of chlorine products consequently go to the Continent from this country; our production of hydrochloric acid being still sufficient to enable us to supply,

not only the total English demand for chlorine and the total American demand for chlorine, but also an appreciable proportion of the Continental demand for chlorine, and, in addition to all that, to throw a large residue of hydrochloric acid into the North Sea. The Continental Leblanc soda makers do not like this importation into their respective countries of chlorine products from England; but they can prevent it only in one or other of two ways; either by increasing their production of hydrochloric acid, or by becoming enabled to obtain from a given quantity of hydrochloric acid a larger proportion of free chlorine than is yielded by the process at present in use. Personally, I have for the process at present in use that respect which one always feels for the bridge which has carried one over, but I am well aware that it can by no means be regarded as final. It yields chlorine cheaply; but it yields only one-third of the total chlorine contained in the acid employed, the other two-thirds being lost as calcium chloride. English chlorine manufacturers will regard almost with horror the idea of a new chlorine process which shall yield in the free state practically the whole of the chlorine contained in the acid employed; but on the Continent there is a demand for such a process; a demand which will no doubt be lessened, but will by no means be destroyed, by what is being done in France by the Compagnie d'Exploitation, and I am one of those who have been called upon to endeavor to supply that demand. M. Pechiney is now preparing to make, at Salindres, a trial on an industrial scale, of a process which, I think, will supply it; and by the end of this year he will probably have obtained decisive results.

As regards the English chlorine industry, however, I do not think that its prospects are by any means so gloomy as, from what I have said so far, might at first blush appear. But I think that its salvation will come from an unexpected quarter. I think that our English manufacturers of Leblanc soda will have to cease to devote their hydrochloric acid, when they do not throw it away, exclusively to chlorine making. They would, of course, be only too glad to do so, if a means could be furnished them of turning it to account otherwise. But the difficulty hitherto has been as to how to turn it to account otherwise. I believe that that difficulty is about to disappear. I am not free to enter into that matter now, and, indeed, it is not yet ripe for discussion; but I have very great confidence that new applications of hydrochloric acid, admitting of being applied very extensively, at

comparatively small expense, are among the things of the immediate future.

As regards soda, the position of the English Leblanc soda makers is this. They are now working, when not actually at a loss, at least without profit. Until comparatively recently, they supplied the whole of the English demand for soda, the whole of the American demand for soda, and a large part of the Continental demand for soda. Both their home market, however, and their American market have been recently invaded by English made ammonia soda, and now the manufacture of ammonia soda has begun in the United States themselves, and will have reached there before the expiration of this year, a scale of 20,000 tons per annum; while a little later on that Belgian soda and copper work of which I spoke, will not only have put an end to all export of English soda to Belgium, but will doubtless also be sending Leblanc soda to America; as will also, no doubt, the great work which is being built at Marseilles, and, eventually, those other works which are about to be built at others of the French seaports. The exportation of English soda to Austria, which has already dwindled to little more than 8,000 tons per annum, is expected to cease entirely before the end of the present year, by reason of the increased quantity of ammonia soda which will soon be made in Austria. An increased production of ammonia soda is similarly expected to put an end, almost immediately, to the importation of English soda into Germany; which importation, in 1881, was already only two-thirds of what it was in 1879. Russia, moreover, will soon be making for herself at least a portion of the soda she consumes; and France, which country has hitherto been entirely dependent upon England for her supplies of caustic soda, though she has long ceased to take from us any other form of soda, will soon be making, herself, all the caustic soda she requires; for, apart from what may be done by the new company of which I have spoken, M. Solvay is just beginning to make caustic soda at Dombasle, and contemplates making it there on a very extensive scale.

In face of all this, how are the English Leblanc soda makers to continue to live? For one thing, it is quite certain that they must have cheaper pyrites. The present price of 6d. per unit is an artificial price, entirely due to a trade combination; and that price will certainly have to be reduced by at least fifty per cent. That it can be reduced to 3d. per unit, and yet leave a very fair profit to the pyrite

sellers, I believe there can be no doubt. At the present price of copper, and at 3d. per unit for sulphur, pyrites showing 2½ per cent. of copper by Swansea assay, would sell for 39s. per ton; and that Spanish pyrites can be delivered to English ports at that price, at a fair profit is, I believe, unquestionable. If, therefore, the existing companies refuse to supply pyrites at that price, they will simply call into existence other companies which will supply it at that price. That the Leblanc soda makers will thus get their sulphur at a price not exceeding 3d. per unit, after the end of next year, when the present combination between the pyrite companies will expire, may be regarded as quite certain.

Pyrites at 3d. per unit, however, would by no means bring down the cost of Leblanc soda to that of ammonia soda. Without using any figures which have been given to me privately, there is no difficulty in arriving, very approximately, at the difference between the cost of ammonia soda and that of Leblanc soda, from what is matter of public knowledge with respect to the dividends paid by joint stock companies which make ammonia soda, and publish balance-sheets. We learn in this way, that when Leblanc soda is yielding no profit at all, ammonia soda is yielding fully £1 per ton. As to make a ton of actual sodium carbonate by the Leblanc process does not require more than about 13·5 cwt. of pyrites, reduction of the price of pyrites to 3d. per unit would thus reduce the cost of Leblanc soda only by about 7s. 9d. per ton of actual sodium carbonate.

Seven shillings and ninepence, however, is something; and, as regards the balance of the pound, there are two resources, which together will, I think, be sufficient to turn the tables upon the ammonia process, and make the good old Leblanc process the cheaper of the two.

One of these two resources consists, of course, in sulphur recovery. If sulphur recovery were the only resource, which, however, happily it is not, I think it not impossible that the required 12s. 3d. per ton of sodium carbonate could be gained by it alone. To this end, except in localities in which there is a demand for sulphuric acid free from arsenic, the sulphur must be recovered, not as sulphuric acid for use again, but as free sulphur, for sale as such. At the general meeting of our Society at Manchester, last July, I explained that, while the Schaffner and Helbig process would yield as sulphuric acid practically the whole of the sulphur of the calcium sulphide contained in the

waste treated by it, it would probably yield as free sulphur only four-fifths of the total sulphur contained in the waste as calcium sulphide. Since then, reason has arisen for a very confident hope that the whole of the sulphur of the calcium sulphide contained in the waste may be obtained in the free state; in which case the yield will be almost exactly 6 cwt. of free sulphur per ton of actual sodium carbonate manufactured. If, therefore, one were dependent for that 12s. 3d. on sulphur recovery alone, the problem would be narrowed to this: Can free sulphur be obtained from alkali waste at such a cost, and is there a sufficient demand for free sulphur at such a price, that it shall be possible to sell recovered sulphur, in sufficient quantity, at 2s. 0½d. per cwt., or say 41s. per ton, more than the cost of producing it?

As regards the demand for free sulphur, the latest returns published by the Italian government show that the average annual production of sulphur in Sicily and Italy, during the five years 1875 to 1879, inclusive, was 282,000 tons, of which 216,000 tons were exported. The total quantity of sulphur that could be produced from English alkali waste does not exceed two-thirds of this latter quantity. The world thus consumes much more sulphur than the English alkali makers could produce, and although to sell all that they could produce they must drive much of the Sicilian sulphur out of the market, in the present "struggle for existence" somebody must go down, and English Leblanc soda makers may be pardoned for preferring that it should be producers of Sicilian sulphur who have to do so rather than themselves.

The actual cost of Sicilian sulphur, delivered at Marseilles, transported in the cheapest way, in bulk, at the purchaser's risk, is about £5 per ton. To become masters of the sulphur market, and at the same time to gain by recovered sulphur the required 2s. per cwt., English soda makers must thus be able to recover sulphur at a cost not exceeding, say about £2 per ton. They will hardly be able to do that at first, but I think that eventually they will be able to do it. If so, and if chlorine products should again command, as I think they will again command, a reasonable price,—for a price which scarcely pays their cost, is, of course, not a reasonable price,—the Leblanc process will at least be able to hold its own, even without that other resource to which I have referred, and which I will now proceed to indicate.

There has come to me from Newcastle a very bold, but, I venture to think, quite practical suggestion, the result of which can hardly fail

to be of enormous importance, not only to the soda industry, but to almost all industries whatever. That suggestion is that the soda maker should entirely cease to use raw coal as fuel, but should convert all his coal into coke, collecting for sale the oil and ammonia evolved during its conversion into coke, and himself using for heating purposes the gases evolved during the coking operation and the coke itself. It is believed, that in the Newcastle district at any rate, by this mode of proceeding the soda maker would obtain his fuel virtually for nothing. In that district there is produced per annum some two millions of tons of very small coal or "duff," which is almost a waste product, and which, singularly enough, yields more oil than the more costly kinds of Newcastle coal, while at the same time yielding a very fair coke, sufficiently good, at any rate, for use in the furnaces of chemical works, especially when its combustion is assisted by that of the gases from the ovens in which the coke is produced; and the value of the oil and ammonia obtained when this "duff" is coked in ovens to which the Jameson system is applied is greater than the cost of the "duff," *plus* the cost of coking it. And it is probable that improved condensing arrangements will render the yield, if not of oil, at any rate of ammonia, so much greater than the yield hitherto actually realized, as to enable the same result to be obtained in the case of ordinary steam coal, not only in the Newcastle district, but in the Lancashire district also. If so, the cost of producing Leblanc soda in both districts will be diminished by almost the total amount of the present cost of Leblanc soda for fuel. I say "almost," because, so far as one can see, the use of raw coal for "mixing" in the black-ash process must still be continued.

And it seems to me that this idea cannot but be as applicable to almost all other industries as to the soda industry, while the result to the material well-being of mankind of its general application, it is utterly beyond the power of any imagination adequately to conceive. This idea means, among other things, cheaper fuel for all purposes, an enormously increased supply of agricultural produce, and the entire suppression of smoke, even in the busiest centres of industry.

And for my own part I venture to think that the same idea might be applied even to the fuel required for domestic purposes, rendering London absolutely free from smoke, and pea-soup fogs, things only of tradition. I think that the time will come when our gas works will be replaced, at least to a large extent, by establishments in which coal

will be treated for the production of coke, illuminating oils, ammonia, and heating gases, the coke to be burnt in our domestic fire-places, the oils to be used for lighting the interiors of our houses, the ammonia to be employed in agriculture, to cheapen and render more abundant our supplies of food, and the gases to be burnt for raising steam for driving dynamos for lighting our streets by the electric arc.

Coming back to soda. If the suggestion in question will enable makers of Leblanc soda in certain districts, to obtain their fuel for nothing, it will, of course, enable makers of ammonia soda, in similar districts, to do the same. How then will it help the Leblanc soda makers? While the quantity of fuel consumed in the ammonia process is only 150 per cent. on the soda produced, the quantity consumed in the Leblanc process is about 350 per cent. on the soda produced. This lower consumption of coal in the ammonia process than in the Leblanc process has hitherto been one of the chief advantages of the ammonia process; but fuel for nothing will so far convert this advantage into a disadvantage that it will reduce the cost of ammonia soda per ton only by the cost of one and a half tons of fuel, while it will reduce the cost of Leblanc soda per ton by the cost of fully twice that quantity of fuel. No doubt this result will be accompanied by some diminution in that heavy item in the cost of ammonia soda which is due to loss of ammonia; but still I think that the balance of advantage will be on the side of the Leblanc process. It can only fail to be so by reason of ammonia falling to one-half of its present price. The price of ammonia unquestionably will fall; but I think that increased use of ammonia in agriculture will prevent its price falling to anything like that extent.

Here the present paper might very well have ended, but I know that it is expected by some of the members present that I should say something on the present state of the sulphur recovery question; and I have therefore to ask permission to go on a little longer in order to do so.

In order to render intelligible some interesting results relating in some degree to the commercial side of the Schaffner and Helbig process, which were obtained at Oldbury in the autumn, and which I have permission to report this evening, allow me to remind you that the two main operations of that process consist: first, in decomposing the calcium sulphide contained in alkali waste by heating the waste with solution of magnesium chloride, whereby there is obtained, on the one

hand, H_2S, and, on the other, solution of calcium chloride holding magnesium hydrate in suspension; and, secondly, in regenerating magnesium chloride for use again by treating that mixture of magnesium hydrate and solution of calcium of chloride by CO_2:

FIRST OPERATION.

$$CaS + MgCl_2 + 2H_2O = H_2S + CaCl_2 + MgH_2O_2.$$

SECOND OPERATION.

$$CaCl_2 + MgH_2O_2 + CO_2 = MgCl_2 + CaCO_3 + H_2O.$$

During the construction of their new plant, Messrs. Chance Brothers made a series of quantitative experiments, upon a scale of half a ton of waste per operation, mainly with a view to determining quantitatively the loss of magnesia involved in the process. These experiments were conducted by Mr. Frederick Chance, a young member of the firm, who has only to fulfil the promise of his youth to take a very high rank among industrial chemists, and their results are interesting and to a certain extent important. By making a number of successive operations without adding any fresh magnesia or magnesium chloride, and comparing the quantity of magnesium chloride which he had at at the end of the series of operations with the quantity which he had at the beginning, Mr. Frederick Chance found that the average loss of magnesia corresponded to 1·05 parts of MgO per 100 parts of waste treated. Now, while in the waste produced at Oldbury there is no magnesia to speak of, a very pure limestone being used there for making black-ash, there is reason to believe that the waste produced in the Newcastle district, the limestone of which district is all more or less magnesium, contains fully enough magnesia to make up this amount of loss, without the addition of any magnesium compound specially for that purpose. All that should be needed, therefore, in the case of Newcastle waste, should be to add from time to time the quantity of calcium chloride necessary to convert into magnesium chloride, by the aid of CO_2, the magnesia actually existing in the waste itself. In other cases, the loss of magnesia in the Schaffner and Helbig process might be made up by replacing two or three per cent. of the limestone used for making black-ash by dolomite. This is supposing, of course, that the calcium carbonate recovered in the process is not used again in black-ash making. In proportion as this recovered carbonate can be used again for making black-ash, there will be no

loss of magnesia; the magnesia "lost" in one operation coming round again in the next.

The experiments of Mr. Frederick Chance further brought out the important fact that the reaction by which magnesium chloride and calcium carbonate are recovered takes place, at any rate under the conditions under which he operated, *i. e.*, under a pressure of twenty pounds per square inch, quite as readily when the mixture treated by CO_2 is hot as when that mixture is cold. It has been supposed that that reaction depends upon the formation of bicarbonate of magnesia, in which case the mixture in question would have required to be cooled before being treated by CO_2, and so to cool it would have been at least troublesome. It seems, however, that the reaction in question is really a reaction between $CaCl_2$ and $MgCO_3$. This result is confirmed by the result obtained by Dr. Hewitt by simply mixing with solution of $CaCl_2$ an equivalent of the carbonate of magnesia of the shops. He obtained in that way a decomposition of about 80 per cent. of his calcium chloride, and it is probable that the carbonate of magnesia he employed did not contain more than that percentage of $MgCO_3$.

Mr. Frederick Chance further lighted upon a very curious fact, which is valuable as affording to the workmen a simple and ready indication of the moment at which the regeneration of the magnesium chloride has become complete. In the mixture operated upon there is always a little ferrous sulphide. This ferrous sulphide is not acted upon by CO_2 so long as there is any free magnesia present, but it is attacked so soon as all the magnesia present has become carbonated, with the result of sending iron into solution as acid ferrous carbonate. The presence of the iron which thus comes into solution can be very readily detected, and the moment it appears the workmen in charge know that it is time to stop injecting CO_2.

In the South of France, experiments are now being made, at my instance, with a modification of the Schaffner and Helbig process. Most of those in France who make salt from sea water content themselves with obtaining therefrom only common salt; but M. Pechiney treats the mother liquors from which as much NaCl as possible has been crystallized out for the further obtainment from them of sodium sulphate, magnesium sulphate, and potassium chloride, and his final residue is a saturated solution of magnesium chloride, containing no other body except magnesium bromide. It has seemed to me that this magnesium chloride might be utilized at once for the recovery of sul-

phur from soda waste, and as a source of magnesia for sale as such. When alkali waste, however, is treated directly by solution of magnesium chloride, the magnesium hydrate, which is one of the products of the reaction which takes place, is obtained in admixture with all the numerous bodies other than calcium sulphide, which were contained in the waste treated. When the magnesium hydrate is to be employed for the regeneration of magnesium chloride, this presence with it of foreign bodies does not matter; but in cases in which regeneration of the magnesium chloride used is not necessary, while it is desired to obtain magnesium hydrate for sale, the presence of foreign bodies with the magnesium hydrate must be avoided. I propose to avoid it by taking advantage of a reaction which is known as Kraushaar's, from its having been first published, in "Dingler's Journal," for 1877, by Dr. Kraushaar, of Thann, but which was really first discovered by Mr. Helbig, at Aussig, and turned by him to practical account there as early as 1874. This is the reaction which takes place when alkali waste is heated with water under pressure. It is a reaction of two of water upon two of calcium sulphide, giving one of calcium hydrate and one of calcium sulphydrate. The calcium sulphydrate is obtained in solution; and if this solution be separated from the calcium hydrate and other bodies which it at first holds in suspension, on then running into it a solution of magnesium chloride there is obtained, on the one hand, H_2S, and on the other, magnesium hydrate, almost chemically pure. And it is to be noted that, whereas when alkali waste is treated directly with solution of magnesium chloride, only one of H_2S is obtained for each equivalent of $MgCl_2$ which enters into reaction, by first getting the sulphur of the waste into the state of calcium sulphydrate two equivalents of H_2S are obtained for each equivalent of magnesium chloride decomposed.

At one time I had some hope that one might take advantage in England of this reaction of two of water upon two of waste to the end of reducing by one-half the quantity of magnesium chloride to be employed, and consequently the quantity of that body to be recovered, per given quantity of alkali waste treated. Mr. Chance was so obliging as to make some experiments on this point at Oldbury, and Mr. Helbig made others at Aussig, and the result of both series of experiments went to show that the idea is not applicable, or at any rate not applicable with any great advantage, when the magnesium chloride employed has to be regenerated. The reason is that the whole of the

sulphur of the calcium sulphide of the waste which is heated with water under pressure does not come into solution unless a certain minimum quantity of water be used. This quantity of water is not too great to permit of the method being employed with advantage when the magnesium chloride has not to be recovered. But when it has to be recovered all this water would have afterwards to be driven off by evaporation, or the regenerated magnesium chloride would be impracticably dilute; and the cost of this additional evaporation would probably balance the economy due to halving the quantity of magnesium chloride to be dealt with.

Some attention has been drawn recently to a second Austrian method of recovering sulphur from alkali waste, a method proposed by Herr Opl, of the chemical works of Hruschau, in Moravia. This gentleman proposes to mix waste with water, to treat the mixture with CO_2 and so drive off H_2S from it, and then to pass this H_2S into more mixture of waste with water, in order that it shall be absorbed by the calcium sulphide of this second quantity of waste with formation of solution of calcium sulphydrate, which could then be treated in any one of several ways. This proposal seems to me defective, for the reason, among others, that I do not see how it would be practicable to avoid sending an excess of CO_2 into the second quantity of mixture of waste and water, which excess of CO_2 would react on some of the calcium sulphydrate formed in that second quantity of such mixture, driving off H_2S, and so occasioning both loss of sulphur and nuisance. Certainly, Herr Opl's method of getting the sulphur of alkali waste into the solution as calcium sulphydrate cannot, I think, compete with the simpler method of heating the waste with water under pressure.

Here, at last, I draw this too long paper to a close. I have had to show in it that the immediate future of the English Leblanc soda industry is somewhat gloomy; but I trust that I have shown also reason to believe that sufficient attention to the complete utilization of all raw materials is yet capable of saving it.

Faure's Secondary Pile.—In Planté's battery the formation of the current is limited by the thickness of the leaden plates. Faure gives to his couples an almost unlimited power of accumulation, by covering the electrodes by a layer of spongy lead. In a pile of 75 kilogrammes he is able to store a quantity of energy sufficient to furnish a horse power for an hour.—*Comptes Rendus.* C.

Experiments upon Electric Lamps.—The French committee have reported the results of their experiments with the Jablochkoff, Debrun, and Jamin lamps, when run by the Debrun, Gramme, and Meritens dynamo machines. They find that the different lamps and machines produce economical results which are almost identical, whether measured by the amount of light furnished per horse-power or by the electric efficiency of the light.—*Comptes Rendus*, Nov. 13, 1882. C.

Optical Study of Elasticity.—Lœwy and Tresca describe an apparatus for the accurate optical measurement of the flexion that is produced in tubes and bars, and give rules for its employment in determining co-efficients of elasticity. They claim for their method three principal advantages. 1. The results obtained by different methods check one another, so as to give conclusions of great precision. 2. The apparatus is so arranged as to prevent systematic errors. 3. The values obtained vary as the square of the flexion, so that accidental errors have but a slight influence. The sensibility of the apparatus is such that the addition of a single gramme produces an effect which can be easily measured.—*Comptes Rendus*, Dec. 4, 1882. C.

Digestive Power of Papaine.—Adam Wurtz reports an experiment, in which papaine dissolved a thousand times its weight of moist fibrine, the greatest part of which was transformed into peptone, not precipitable by nitric acid and which, by means of a complete hydration of the fibrine, even formed a small quantity of a crystallizable starchy substance, such as is often observed in good pepsinic digestions. In another experiment, 0·05 gramme (0·77 grain) of the same papaine liquefied 100 grammes, or 2,000 times its own weight, of moist fibrine, with the exception of a trifling residue of dyspeptone. From these experiments he concluded that the ferment, being of an albuminoid nature, could operate on itself so as to hydrate itself. Experiments showed that this anticipation was correct. In one case, 17 grammes of fibrine were divided as fine as possible, by means of scissors, then put in contact for a few minutes, at an ordinary temperature, with a weak solution of papaine, then pressed and washed for half an hour under a strong jet of water, and then washed thoroughly with distilled water. The fibrine, after this pressure and repeated washings, was digested at 40° (104°F.) with 75 cubic centimetres of pure water. On the next day the solution was complete, with the exception of about one per cent. of dry dyspeptone.—*Comptes Rendus.*

Origin of Thermo-Electricity.—The thermo-electric batteries, and especially those of M. Clamond, had raised large expectations because the corrosion of the solderings was attributed to heat alone, and it was hoped that it might be remedied. Exner has just shown that it is due to oxidation by the air, aided by the heat; and that if this action was prevented, by the use of nitrogen, for example, the electric current would not be formed. Thermo-electric batteries are, therefore, simply gas-batteries, in which certain gaseous fluids act in a similar manner to acid liquids.—*Chron. Industr.* C.

Movements of Submerged Bodies.—In defending his hypothesis against the attacks of French academicians, Dr. Siemons refers to the experiments of Froude, at Torquay, under the direction of the English Admiralty. He arrived at the unexpected result, that a submerged body, if it moves with a uniform velocity through a perfect fluid, will encounter no resistance whatever. By a "perfect fluid" he understood a fluid free from viscosity or *quasi* solidity and in which no friction is caused by the gliding of its particles over one another or over the surface of the body. The luminiferous æther is presumably such a fluid, and the discussion of Siemen's theory cannot be settled until all the consequences of perfect fluidity are duly settled.—*Comptes Rendus*, Nov. 27, 1882. C.

Malleable Nickel.—Pure nickel, after melting and casting, generally holds a greater or less quantity of oxygen in solution and the metal is brittle. To hinder the injurious effects of the oxygen, it is necessary to incorporate in the melted nickel some substance which has a strong affinity for oxygen and also for the nickel itself. J. Garnier finds that phosphorus serves both of these purposes very satisfactorily, producing effects analogous to those of carbon in iron. If the phosphorus does not exceed $\frac{3}{10}$ of one per cent. the nickel is soft and very malleable; above this quantity the hardness increases at the expense of the malleability. Phosphorized nickel, when alloyed with copper, zinc or iron, gives results which are far superior to those that are obtained from the same nickel when not phosphorized. By means of the phosphorus, Garnier has been able to alloy nickel and iron in all proportions and always to obtain soft and malleable products. The contradictions of illustrious chemists are thus explained, some saying that such alloys were brittle, others that they were malleable; the latter had alloyed the nickel to phosphorized iron.—*Comptes Rendus.* C.

Newcastle Coal.—The Newcastle basin is now yielding an average annual product of 35,000,000 tons. The beds extend under the sea, and there has been some question as to the limiting depth at which they can be worked. Even at the most moderate estimates, it is thought that there are at least seven thousand million tons which can be readily mined, which would be enough to continue the present supply for two hundred years.—*Les Mondes*, Dec. 2, 1882. C.

Purification of Ores by Air Blast.—In the neighborhood of Genolhac there are large quantities of ochreous earth, containing some threads of galena, but in no instance does the proportion of lead exceed seven per cent. The ore is consequently very poor, but it is so abundant that attempts have been made to enrich it by the ordinary processes of washing. These attempts having failed, it occurred to the engineers to try air, which was forced through three superposed metallic cloths, with meshes of four, five and ten millimetres (·157, ·197, ·394 inches), respectively. The air, being thus perfectly divided, reaches a rectangular box, at the extremity of which a hopper distributes regularly the dried and pulverized materials which it is desired to classify. The worthless portions, being the lightest, are easily driven off by the blast; while the leaden particles, being heaviest, are carried to the bottom.—*Comptes Rendus.* C.

Objections to Siemens' Theory.—G. A. Hirn calls attention to the investigations of Henry Sainte-Claire Deville, which indicate that none of the known chemical compounds could exist at the surface of of the sun. He thinks, therefore, that the compounds that Siemens supposes to be gradually dissociated by solar radiation would be recombined at some distance from the photosphere, and that the compounds would again be dissociated before reaching the sun's surface. This act would require all the heat which had been developed by the combination, so that it would contribute nothing to the conservation of solar radiation. He agrees with Faye in thinking that an absolute material vacuum is required to secure the stability of movement which has been found by astronomers. This vacuum is at variance with the doctrine which attributes all physical phenomena to the movements and shocks of independent atoms. He thinks that the defenders of this doctrine will some time be compelled to admit the existence of some immaterial agency, such as Newton recognized in his remarkable letter to Bentley. —*Comptes Rendus*, Nov. 6, 1882. C.

Utilization of Cinders and Coal Refuse.—Noack Dollfus has prepared a valuable paper upon the preparation of beton from slag and other refuse, by the addition of about 20 per cent. of lime. By using the methods and precautions which he points out, foundation walls and superstructures of great strength and durability can be made. —*Soc. Industr. de Mullhouse.* C.

New Determination of the Mechanical Equivalent of Heat.—Prof. A. Bartoli has recently found the value of 428·4 kilogrammetres (771·12 ft. lbs.) for the mechanical equivalent of heat, by the following method. He used a steel tube into which he introduced a known quantity of mercury at a pressure accurately determined and at the temperature of freezing water. The interior diameter of the tube was so small, and the length so greatt, that the mercury, on its exit from the tube, had scarcely any velocity. Keeping the temperature of the tube at the freezing point by means of ice, he measured the quantity of ice melted and thus estimated the quantity of heat developed.—*Riv. Sci. Industr.* C.

New Theory of Gases.—A. Gouilly proposes to give to thermodynamics an experimental point of departure of a greater generality than the laws of Mariotte and Gay-Lussac. He starts from the proposition that the calorific capacities of gases under constant pressure and under constant volume, are independent of the pressure and of the volume. In order to calculate the function γ, so that $\frac{dQ}{\gamma}$ is an exact differential, it is not necessary to adopt the hypothesis of the perfect gaseous condition, which is now applicable to none of the known gases. It is preferable to take the gaseous property which is defined by the expression $\frac{dC}{dp} = 0$. For, while the laws of Mariotte and Gay-Lussac are not rigidly true, experiment shows, in a very precise manner, at least for hydrogen and air, that the calorific capacity under constant pressure is independent of the pressure. In admitting for gases that the two specific heats are independent of the pressure and of the temperature, we find an equation with three coefficients which represents, even for carbonic acid, the laws of compressibility and of dilatation, so that the natural gases approximate the condition defined by this equation, while they all deviate from the condition of a perfect gas.—*Soc. des Ing. Civ.*, Nov., 1882. C.

Coloring Jewelry by Galvanism.—Fr. Weil has exhibited to the French Academy various articles of jewelry, which were colored by metallic layers deposited by electro-chemical processes. The colors have a great artistic value and are very durable, resisting friction, moisture, sulphuretted hydrogen, vapors of ordinary burning gas, and the action of light. Edmond Becquerel recalled the experiments of his father, in coloring metals by means of thin layers of oxide of lead and oxide of iron. He obtained very brilliant shades of various colors, and he found that by increasing the thickness of the layers, he could effectually protect metals from rust.—*Comptes Rendus*, Nov. 20, 1882.

Motion of Sun Spots.—Spœrer, in a letter to Faye, reports the results of comparisons of his observations for twenty years, which seem to indicate a slight tendency in sun spots to move towards the equator between the parallels of 5° and 10°, and a slight tendency to move towards the poles between the parallels of 20° and 25°. Carrington and de' Rico found that the direction towards the equator predominated up to 15° of latitude, and towards the poles in higher latitudes. The tendencies were so slight that Carrington did not attach any importance to them. Faye regards these results as fatal to the hypothesis of Siemens, for if the sun is fed by an influx at the poles, he thinks that there should be a uniform tendency of the spots towards the equator in all latitudes.—*Comptes Rendus*, Dec. 4, 1882. C.

Twinkling during Auroras.—Arago, in his admirable note on Scintillation, says that at the end of the 18th century Dr. Usher remarked, that at Dublin the Northern Lights make the stars singularly undulating in telescopes, and that according to Neckers, de Saussure, and Forbes, the stars do not twinkle in Scotland unless there is an aurora visible. Montigny's observations of scintillation have coincided with many visible auroras. At each one of those coincidences the intensity of the scintillation was much greater at the moment of the aurora than on the previous evening or on the following day, when the atmospheric conditions were the same but no aurora was seen. When a magnetic perturbation is noticed at the Brussels observatory without any accompanying visible aurora, the intensity of the scintillation suddenly increases, and it is then much greater than on the previous evening or on the following day under the same atmospheric conditions, with the exception of the magnetic perturbations.—*Comptes Rendus*, Feb. 26, 1883. C.

Celestial Physics.—Before starting upon the eclipse expedition, Janssen sent a communication to the French Academy, upon problems which he is investigating. By means of the photographic revolver, he finds that the movements of the granular matter of the sun are so rapid that the appearance of any photospheric region changes at very brief intervals; sometimes the space of a second is sufficient to bring about a complete change in the form of a granular element. The velocity of the movements is extremely variable, but it is generally of the same order of magnitude as those which Lockyer has observed in the gaseous matter of solar eruptions. He has long been occupied with the study of the spectrum of water vapor, but he has been subject to frequent interruptions on account of the interference of other engagements and the difficulty of constructing the extensive apparatus which is required. He hopes soon to be able to present to the Academy a complete discussion of the spectrum, covering the whole range, from the obscure heat to the ultra-violet. The knowledge of the vapor spectrum is indispensable for determining the origin of a large portion of the telluric rays; it is equally important in the study of planetary atmospheres. In the stars it may conduct us to entirely new notions about the temperature of their atmospheres.—*Comptes Rendus*, Feb. 26, 1883. C.

THE METAL OF THE FUTURE.

[From the Report of the Secretary at the Stated Meeting held May 16, 1883.]

The technical papers for the past month or two have been full of accounts of a new process for manufacturing the metal aluminium, said to have originated in England, and by which, it is affirmed in very positive terms, the price of this metal has been reduced from $5,000 per ton to $500, or to about 25 cents per pound. I shall in the proper place subject this alleged new process of manufacture to the test of criticism, to judge of the validity of the claims made in its behalf, but first will take the opportunity of giving the subject of aluminium—the metal of clay—a general consideration,

Aluminium, the metallic basis of clay, is even more widely disseminated over the surface of the earth than iron. It is one of the constituents of the minerals feldspar and mica, of which the granites and gneisses are largely made up, and of the clays which result from the

disintegration of these rocks. It exists in considerable quantities, also, in nearly all the so-called crystalline rocks, and the silicates of alumina in various combinations form the most numerous class of minerals.

Abundant as are the ores of this metal, it is one of the most difficult to reduce. Shortly after the discovery, near the beginning of this century, by Sir Humphrey Davy, that the so-called earths, soda, potash, lime, alumina, etc., were metallic oxides, and not simple bodies, as had hitherto been supposed, and his demonstration of the fact by isolating the metals sodium and potassium with the aid of the then newly discoverd galvanic battery, repeated attempts were made also to isolate aluminium, the metal of clay, but unsuccessfully, until at length, after many failures, the efforts of Wöhler were crowned with success in the year 1817. The properties of the new metal were found to be so remarkable that the attention of chemists was at once attracted to the subject of its production; but the metal obstinately resisted all efforts to produce it in quantity until the year 1854, when St. Claire Deville solved the problem measurably, by reducing the metal from anhydrous chloride by reduction with metallic sodium. It was thought then that the successful solution of the problem of producing aluminium on the commercial scale would speedily bring about a revolution in the metallurgical world. But though nearly thirty years have elapsed since that time, aluminium is still, by reason of its high price, ranked among the more precious metals, and is consequently debarred from competition with copper, zinc, tin, iron and steel for the numerous industrial uses for which it is well adapted, by reason of its many admirable and unique qualities. What these are will appear from the following brief rehearsal:

The metal aluminium has a grayish-white color, between that of zinc and tin; it is exceedingly light, being only two and a half times heavier than water—that is, about three and a half times lighter than copper, four times lighter than silver, and nearly eight times lighter than gold. It is remarkably sonorous, giving out a very clear musical tone when struck; it is very unchangeable in the atmosphere, surpassing in this respect most of the baser metals—iron, copper, etc., and resembling the precious metals silver and gold. It is very difficultly oxidizable, nitric acid (aqua fortis), which attacks and destroys nearly all the metals with the greatest energy, having little or no action upon it, and even the white heat of the furnace only suffices to oxidize it superficially. It has a tensile strength equal to that of copper, and conducts electri-

city nearly four times better than iron. It forms alloys with many of the metals, many of which have remarkable qualities. Of these alloys, those with copper—the so-called aluminium bronzes—are the most notable, being possessed of such valuable properties that their extensive adoption in the arts is only hindered by the one circumstance of their comparatively high cost.

From the above brief *resumé* of the leading characteristics of this remarkable metal, it will be at once apparent that a wide field would at once be opened for it, in almost every department of industry, if once the problem of its cheap production were solved; and assuming the truth of the newspaper accounts respecting the alleged new process of producing it in England at 25 cents per pound, the statement that the invention would "effect important changes in the metal trade, not only in England but throughout the world," is not in the least exaggerated.

Unfortunately, however, the alleged new procedure of Mr. Webster, of Hollywood, near Birmingham, which has been the recipient of a larger share of gratuitous advertising than any other patented process that has appeared for some years, will not bear a critical investigation. The process embraces two principal elements—the preparation of an anhydrous chloride of aluminium, or of a double chloride of aluminium and sodium, by a very tedious and roundabout method; and from this chloride, the metal is subsequently obtained by the use of sodium as a reducing agent.

I was greatly interested in getting at the details of this new process. Months before anything was published concerning it, it was whispered in scientific circles in England that the problem of the cheap production of aluminium had at length been solved. Even so eminent a luminary in the metallurgical world as Sir Henry Bessemer, in an address before one of the leading British engineering bodies, foreshadowed the announcement of some remarkable discovery, and set all the scientific world agog with curiosity. At length, after some months of patient waiting, the technical journals of England announced the procedure of Mr. Webster with a grand flourish of trumpets, the American journals have taken up the refrain, and it appeared to occur to no one to subject the extravagant claims of the alleged improvement to the test of intelligent criticism. For myself, I cannot refrain from the statement that I was more than astonished that claims so grossly and palpably erroneous and exaggerated should have been permitted

to pass unchallenged in the country where they originated, and which boasts of so many eminent authorities in metallurgy.

The alleged new process is almost a literal copy of the old, time-honored method introduced and practiced in France for the past twenty years. In the only important features—namely, the production of an anhydrous chloride, and the reduction of this by means of sodium, it is absolutely the same. The only features that can be called new, relate to the method of treating the raw material some convenient and cheap aluminous substance, and after reading Mr. Webster's patent specification, I am well satisfied that those portions of the process that are new are the only portions that are worthless.

All this may seem to be unnecessarily severe upon Mr. Webster, but in explanation, I have to urge that when an inventor publishes his invention with such extravagance of statement, he must expect the most searching investigation of his claims. The utter absurdity of Mr. Webster's claim to be able to produce aluminium at a cost of £100 (about $500) per ton, which would be equal to about 25 cents per pound, will appear from the simple statement, that to reduce one pound of the metal from the chloride, requires, theoretically, very nearly three pounds of metallic sodium, and in practice nearer four pounds than three, and the cost of the sodium alone required for the reduction of a pound of the metal will be almost one dollar, if not more, to say nothing of the tedious and costly preparation of the chloride. But I have said enough. Aluminium, I am satisfied, is the coming metal, destined one day to play as prominent part in the arts of civilization, perhaps, as iron, but after raising our expectations to so exalted a pitch, Mr. Webster's much advertised solution of the problem of producing it cheaply forcibly recalls to memory, by the similarity of its descent from the sublime to the ridiculous, the old quotation: "*Parturiunt montes, nascetur ridiculus mus.*"

Artificial Filtering Stone.—K. Steinman, in *Tiefenfurt bei Görlitz*, proposes filtering plates from the following mixture:

Clay	10 parts, or	10 or	15
Levigated chalk	1	1	1
Glass sand, coarse	55	..	...
" fine	...	25	65
Ground flint	...	30	5

The ingredients are mixed thoroughly in water, moulded, and hard burnt.—*Dingler's Journal.* C.

THE DRAWING SCHOOL.

On Friday evening, May 11th, a large audience of pupils, their friends and members of the Institute assembled in the Hall to take part in the closing exercises of the Drawing School.

The exercises comprised the exhibition of several hundred drawings (mechanical, architectural and free-hand), the work of the pupils of the school, addresses by several of the officers and members, the reading of the annual report of the Director of the school, and the delivery of the diplomas to those who had satisfactorily completed a full course of study in the school.

The proceedings were opened with an appropriate address by the President of the Institute, Mr. Wm. P. Tatham. After explaining the purpose of the meeting, he spoke of the great satisfaction with which the Board of Managers regarded the present very prosperous condition of the Drawing School. This satisfaction, he said, originated not only because of the unprecedentedly large number of the pupils who attended the school during the past year, but also from the unusual excellence of their work as shown by the specimens on exhibition, which demonstrated at once the thoroughness of the instruction, the faithfulness of the teachers and the assiduity of the pupils.

The Secretary then read the report of Mr. Wm. H. Thorne, Director of the school.

Annual Report of the Director of the Drawing School of the Franklin Institute for the Sessions 1882–1883.

That the importance of some knowledge of the Art of Drawing is becoming more appreciated every year is evidenced by the annual increase in the number of students in this school. It is a promising sign, for there is no sphere, in which the ability to express conceptions of beauty of form and design, or ideas of mechanical devices and constructions, by means of lines drawn on paper in such a manner as to accurately convey these conceptions to others, will not prove of great value. The boy who attempts to make a bird-box, will save time, vexation and material, if he is able to plan it on paper, altering the design until it suits his fancy and arranging the details and method of construction before he commences the work. So the millionaire, who is about to have a mansion built, if he is able to understand the architect's plans, can criticise, suggest alterations and devise conveniences, which will place the stamp of his own individuality upon it and prove a source of just pride. To one engaged in a mechanical or industrial

pursuit, a knowledge of drawing is coming to be indispensable, and those who do not possess it will inevitably fall behind in the race. To quote from the recently published autobiography of the eminent Scotch engineer, James Nasmyth: "Mechanical drawing is the alphabet of the engineer; without it the workman is merely a hand; with it he indicates the possession of a head." It is of more or less importance in all pursuits, and that this is understood is shown by the number and the vocations of the students in our school.

The number of students this year amounted to 402, of whom 210 attended the winter term and 192 the spring term. In each term, the school was divided into seven classes with an instructor for each class, and instruction was given four evenings in the week instead of two as heretofore, on account of limited accommodations.

The progress made has been very satisfactory and that some good work has been done is shown by the examples exhibited. The interest taken in theoretical drawing is encouraging, as particular attention has been given to the thorough and correct teaching of the principles of projections and intersections and what is really Descriptive Geometry, stripped of its rules and put into a practical and modern form. Many complete Working Drawings, both Mechanical and Architectural have been made in a superior style, not after the ordinary school systems but by the methods employed in our best workshops. In the Free Hand Classes, there has been marked progress, and several of the students have made good drawings from the round. There is a great want of models, casts and appropriate accommodations in this department.

The aim has been to make the instruction practical and useful and to have the classes so graded as to insure systematic progress. The teaching includes correct manipulation, the geometry of drawing and its application to the useful arts. The instructors have had two difficulties to contend with, one of which is an indifference to accuracy and neatness of execution on the part of some of the students, while the other is the apparent inability of other students to understand the principles involved, although taking great pride in the appearance of their work. But few appreciate the importance of both a thorough understanding of the rationale of the methods employed and also of precision and beauty of execution.

The following list includes those who have shown the most talent, made the most progress and produced the best results, for which Honorable Mention is made of them:

In the Senior Mechanical Classes.—Willis H. Groat, Reinholdt Kuehln, A. M. Hahn, W. J. Bradley, Albert R. Ridgeley, J. F. Braun, Charles A. Eimert, George Eimert, John Louis, M. Morgan.

In the Intermediate Mechanical Classes.—Charles B. Scott, Edw. A. Miller, Alphonso Kirschner, James T. Baker, Jacob Weber, Wm. Levick, Henry H. Brown, Sidney Newbold, E. W. Thomas, Henry Kirst, and Fred'k O'Neill.

In the Junior Mechanical Classes.—James G. Davis, J. N. Butler, Justus Allen, William Nace, Joseph Edel.

In the Architectural Class.—George F. Jackson, A. A. Belfield, James J. Allen, Alfred Richardson, Newman Collins.

In the Free Hand Classes.—G. H. Merchant, J. J. Reutlinger, Charles Bregler, Fred'k Reutlinger, Chas. Fleming, Siegfried Kuder, Max Hindle, Wm. Winneberger, Carrie Ayres.

The following students, having completed a full course of four terms, are recommended for the award of certificates to that effect:

Willis H. Groat, Reinholdt Kuehln, Albert R. Ridgeley, W. J. Bradley, J. F. Braun, A. M. Hahn, G. H. Merchant, J. J. Reutlinger, H. S. McCaffrey, Rudolph Boericke, J. L. Taylor, Wm. B. Thompson, Clark T. Dill, C. G. Whittaker, John Fauser, George Keyser, Charles McDowell, Carroll Lukens, Wm. S. Moore, Harry Casey.

The results of the year are encouraging to the instructors and should be staisfactory to the Institute and also to the pupils, but few of whom have failed to receive benefit from their attendance. The efficiency of the school has been largely due to the ability and hearty co-operation of my assistant instructors, Messrs. Carl Barth, Edw. S. Paxson, C. Claussen, Geo. S. Willets, and Wm. P. Dallett.

Next year the school will be better prepared than ever before to meet the growing demand for practical instruction in Mechanical, Architectural and Free Hand Drawing.

WM. H. THORNE,
Director.

At the close of the reading of the report the diplomas were delivered by the President to the pupils who were entitled to receive them.

After the close of the formal exercises, brief addresses were made by Mr. Hector Orr, Mr. James Fraiser, and the Secretary. An inspection of the drawings on exhibition followed, and the gathering dispersed with the general expression of satisfaction with the work of the school.

W.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON HUGO BILGRAM'S IMPROVEMENT IN GEARING FOR METAL PLANERS.

Philadelphia, Pa., March 20, 1882.

To the Committee of Science and the Arts
of The Franklin Institute, Philadelphia.

GENTLEMEN:—Your committee appointed to examine application No. 1210, Hugo Bilgram's improvement in "gearing for metal planers," met and examined the drawing and description annexed and heard the oral explanation of Mr. Bilgram.

This is a device designed to overcome the objection of wear and lost motion in the ordinary gear for imparting reciprocating motion to the bed of metal planers.

It consists of two independent sets of gear, ingeniously arranged, upon one set of shafts and boxes—one set imparting the slow and working motion and the other the reversing or idle motion. (See detailed description attached).

Each train of gear is driven by the belt, first on the slow and forward train, thus propelling the bed while cutting; then the belt is shifted by the shifting arrangement on to the fast or returning train, and returns the bed quickly, at the same time propelling the first train in the reverse direction, the power being applied through the rack on the bed to the other end of the train. There being no cessation of contact, no points form back lash.

In like manner the reversing train is propelled in its reverse direction, so there is no lost motion or back lash arising from it.

To prevent the trains running beyond the point driven by the bed, by their momentum or that of the driving pulleys, there is placed a frictional leather washer against the sleeve of one train and the axle of the other.

As both trains move in the same direction there is no wear on this washer, indeed no motion except the slight shift that may be occasioned by much wear of the gears after long use.

Your committee are of the opinion that this device is a good and practicable arrangement for correcting the defects and overcoming the annoyance arising from lost motion in the ordinary gear of the planing machine.

HALL OF THE INSTITUTE.

November 1, 1882.

At the stated meeting of the Committee on Science and the Arts, held on above date, it was decided, on motion of Mr. Chabot, to amend the report by incorporating a recommendation for the award of the Scott Legacy Premium and Medal. As so amended the report was adopted.

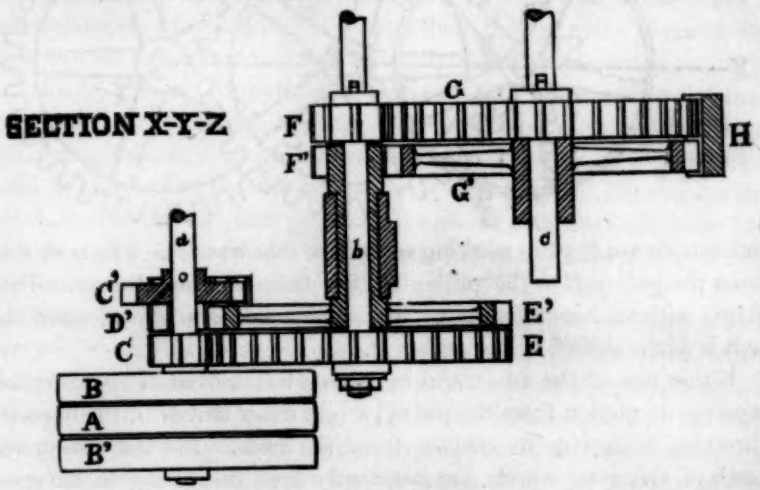
H. R. HEYL,
Chairman.

Attest: WILLIAM H. WAHL,
Secretary.

DETAILED DESCRIPTION.

The object of the invention is to obviate the jar occasioned by the back lash of the gears at the instant of reversal of the motion of the table, which is accomplished by supplying two independent trains of gears to connect the two belt pulleys with the rack of the table.

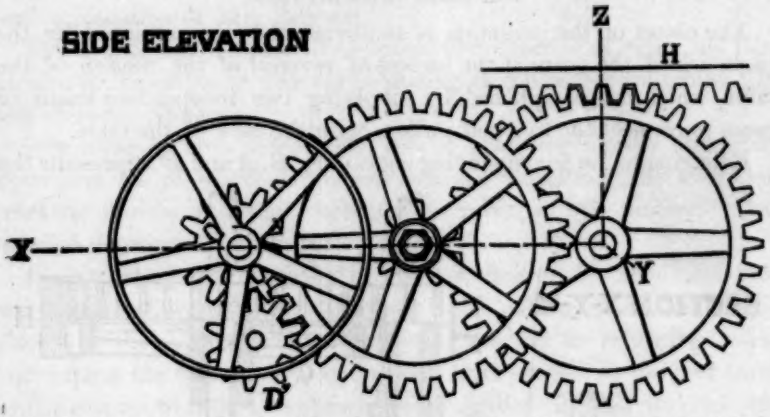
Referring to the accompanying engraving, *B*, *A* and *B'* represents the



belt pulleys, of which *B'* is fixed to the shaft *a*, while the pulley *B*, together with the pinion *C*, to which it is united, is free to turn upon the shaft *a*. *A* is the loose pulley. The pinion *C* engages with the gear *E*, fastened to the shaft *b*, which latter carries the pinion *F*. Upon a third shaft *c*, is fixed the gear *G*, engaging with the rack *H* of the table. Upon the shaft *a*, is fastened a small gear wheel *C'*; another gear wheel *D'* gears both into *C'* and the gear wheel *E'*. By this gear

the reverse motion is produced, though both pulleys in their turn are run in the same direction by the belt. The gear E' is attached to one end of a sleeve e, carrying at its other end the pinion F'. This sleeve is free to turn upon the shaft b. The pinion F' engages with a wheel G', loose on the shaft c, which gears into the rack H. The machine when thus constructed is run by a single belt that may be shifted from one pully to the other.

The two pulleys B and B' are thus connected with the table by two independent trains of gears. When the belt runs on the pulley B, moving the table by the train C, E, F, G, H, the second train C', D', E', F', G', H will be moved by the rack H, whereby the teeth of the



latter train are kept in working contact so that when the belt is shifted from the pulley B to the pulley B', the train is ready for immediate action without loss of motion. The same conditions prevail when the belt is again shifted to the pulley B.

Either one of the two trains of gears when moved in one direction receives its motion from the pulley, while when moved in the opposite direction it derives its motion from the rack. For this reason the teeth of the gear wheels are constantly kept in gearing in the same sense, and hence a jar resulting from back lash is impossible.

Pressure Battery.—A. P. Zazareff has addressed a note to the French Academy relative to an electric pressure battery. The production of electricity is due to the passage of a solution of glycerine, under the action of a pressure which is more or less severe, through a mixture of coke and anthracite.—*Comptes Rendus.* C.

Franklin Institute.

HALL OF THE INSTITUTE, May 16th, 1883.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tathem, in the chair.

There were present 80 members.

The minutes of the last meeting were read and adopted.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held May 9th, 16 persons had been elected to membership.

The several Special Committees reported progress, and were continued.

Mr. Robert Grimshaw read a paper entitled "Comparison of Indicator Rigs," which was discussed by Mr. John W. Nystrom. An abstract of Mr. Grimshaw's paper will appear in the JOURNAL for July.

The Secretary's report embraced a criticism of certain alleged improvements in the manufacture of aluminium; an account of recent improvements in the secondary battery; a brief account of the history and engineering features of the East River bridge, and a description of a number of inventions, among which were the following, viz.:

John G. Baker's meat chopper, designed for butchers, farmers, restaurants, etc. It consists of a hopper and cylinder combined, the latter containing the screw which carries the meat forward. A four-bladed knife is attached to the end of the screw and revolves with it as the crank is turned. A plate perforated with numerous small holes fits into the end of the cylinder and is secured in position by a ring which screws up and clasps the plate tightly against the knife.

The process is as follows: The meat is fed into the hopper and carried forward by the screw until it reaches the perforated plate, when the pressure forces it into each of the small holes in the plate, where it is chopped off by the revolving knife which makes four cuts for each hole, with every revolution of the crank, the small pieces thus cut being forced out by the continuous pressure from the interior of the cylinder.

A number of these machines of various sizes were exhibited, among them being one of large dimensions driven by power, and having a capacity of 1,000 pounds per hour.

The Rue Manufacturing Co.'s Boiler Testing Apparatus, is a combination of two instruments—the one filling the boiler, the other applying the pressure. It is designed to test boilers with warm water under

a continuous even pressure without shock or jar, which, it is affirmed, cannot be done with a pump and cold water.

The Rue Manufacturing Co.'s Boiler Testing Apparatus, is designed to dispense with the usual cold water test. The method consists in filling the boiler full of hot water (say 180° or more), then applying the required pressure by means of an injector constructed for the purpose, which also continues to add heated water to the boiler. A safety or relief valve is set to open at the pressure to which it is desired to test the boiler, and the operation of the injector is such as to accumulate and maintain that pressure constantly and as long as may be required. The apparatus consists, therefore, substantially in the arrangement of an injector and ejector especially constructed and connected for the purposes above described.

Gray's Grindstone Dressing Machine, for truing the faces of grindstones, exhibited on behalf of G. A. Gray & Co., Cincinnati, consists of a series of serrated disks placed in a gang on a rod held in a suitable fixture and brought into contact with the face of the stone to be dressed. The spurs or disks revolve independently and pick the surface instead of scraping it.

Shrieves & Cook's Chemical Underground Electrical Conduit, is made by providing troughs formed of earthenware or other material, which are placed in suitable trenches and the wires stretched therein. The filling employed is a mixture of sulphur and sand or other siliceous material, forced into successive sections of the line in a melted state. This compound is claimed to be "hard, water-proof, and indestructible," and the method is said to afford an excellent insulation, durability, economy and convenience of laying such conduits.

Neracher's Automatic Hose-reel, for mills, warehouses, railway stations, etc., was exhibited by Mr. Wm. H. Johnson. The reel is provided with a permanent connection with the water supply, and the playing out of the hose automatically turns on the water by opening the valve.

The Planetary Car Wheel of Mr. H. G. Yates, consists of a series of friction rolls upon which the axle revolves. These rolls are disposed in such a manner as to reduce friction and wear to a minimum.

Under New Business, Mr. E. Alexander Scott was accredited as a delegate to represent the Institute at the Exhibition of Railway Appliances, about to be held in Chicago. Whereupon, the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*